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ABSTRACT

This abstract is the annual report of NASA's Technology Utilization Program, which is charged with promoting and stimulating the practical application of government-sponsored aerospace technology. The report is organized in three sections: (1) aerospace aims; (2) technology twice used; and (3) technology utilization. Section 1 outlines NASA's major programs in space exploration, aeronautical research and technology application, and described the potential benefits of a direct nature that are accrued from these efforts. Section 2 contains a representative sampling of the indirect benefits resulting from the secondary use of aerospace technology in industry and the economy. Section 3 details the nationwide activities of the Technology Utilization Program in encouraging the broadest possible secondary use of new technology emerging from aerospace programs. The latter section also includes a list of regional NASA officials and others who can be contacted by those seeking NASA technical information or assistance. (Author/BB)

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Spinoff 1978

AN ANNUAL REPORT

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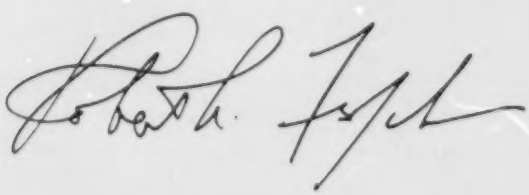
Foreword

This year marks a major milestone for the National Aeronautics & Space Administration: its twentieth anniversary. In the past two decades NASA has spearheaded the most rapid technological advance the world has ever known. Teamed with American industry and the scientific community, NASA has pioneered the use of space for the direct benefit of mankind and for the expansion of human knowledge, taken man to the moon and back, placed automated laboratories on Mars and begun a systematic exploration of the solar system. At the same time, NASA has conducted a program of aeronautical research that has revolutionized atmospheric flight.

Scientific gain is in itself a tangible and valuable benefit, an intellectual resource which serves as the base for expanding technology. Technology provides the ability to improve the quality of life, and it has never been more important than today when it offers a means of solving many of mankind's problems. In future years, the application of new technology will be a key factor in improving our standard of living, our domestic economy, our international trade posture and our prestige among the other nations of the world.

NASA's aerospace programs provide a special stimulus to technological advancement since they involve research and development in virtually every scientific and technological discipline and create an ever-expanding base of knowledge from which a variety of benefits derive. The nature of some of these benefits and how they were derived is the subject of this volume.



Robert A. Frosch

Administrator
National Aeronautics and
Space Administration

January 1978

Spinoff 1978

AN ANNUAL REPORT

National Aeronautics and Space Administration

Office of Space and Terrestrial Applications

Technology Utilization Division

by James J. Haggerty

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Introduction

Some six thousand years ago, an unknown Bronze Age inventor conceived the idea of the wheel, which permitted draft animals to pull greater loads by rolling a cart rather than dragging it. One of man's earliest and most significant technologies, the wheel has been re-adapted countless times over the millenia. In ancient times it provided the departure point for such devices as the potter's wheel, the grindstone, the pulley, the spinning wheel, the lathe and the windlass. The same rotary motion concept is the cornerstone of many modern transportation compoents—for example, gears, rotating shafts, propellers and turbines—and for a great variety of non-transportation conveniences from casters to doorknobs.

The evolution of wheel-derived contrivances is perhaps the broadest example of how technology, once developed, can be transferred to uses different and often remote from the original application. This process of "spinoff" has been going on since the dawn of technology, expanding constantly under the impetus of an ever-widening technology base. In the past 20 years, there has been exceptional acceleration of technology transfer, due in great measure to NASA's aerospace research programs. To meet the goals of space exploration and aeronautical advancement, NASA and its contractors have of necessity developed innovations in virtually every field of science and technology. This storehouse of knowledge provides an extremely broad technical foundation for the stimulation of secondary applications.

The range of spinoffs that have resulted from re-use of aerospace technology is extraordinary; in fact, it is difficult to find a facet of everyday life wherein spinoff has not penetrated. NASA technology has been transferred to medicine, transportation, public safety, industrial processes, pollution control, energy systems, construction, law enforcement, communications, home appliances, farm machinery, sports and recreation, food products—the list can be extended to catalog length.

Within these broad catagories, there have been literally thousands of individual spinoffs. Many are moderate incremental improvements in products and processes for personal convenience or industrial efficiency; many others are important advances of significant public benefit. Collectively they represent a stimulating influence on the national technological process, hence a valuable contribution to the U.S. economy.

Little of the spinoff "just happens"; serendipity does occur on occasion, but it is rare. For the most part technology transfers need a catalyst, a link between available technology and those who might put it to productive re-use. NASA provides the catalyst with its Technology Utilization Program, a dedicated effort which seeks new opportunities to re-apply the wealth of knowledge in the national technology bank and to gain thereby a bonus return on the tax-paid investment in aerospace research and development.

Spinoff is one form of public benefit emerging from NASA's work; there are, in addition, those programs in which technology is being specifically developed and applied for *direct* benefit, as opposed to the *indirect* benefit accruing through spinoff.

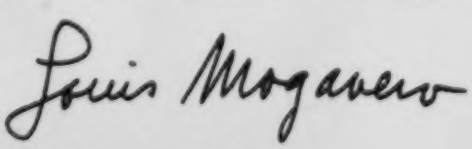
The most familar direct benefit systems are orbiting satellites designed to do Earth jobs which can be better performed from a platform in space, or which can be done only in space. Examples include weather monitoring and communications relay by satellite, or the use of orbiting Earth-survey stations to provide information for improved management of our planet's resources. NASA also develops surface systems designed to meet specific societal needs; an example is the relatively new and rapidly growing effort in energy technology, wherein NASA is applying its technological expertise in support of the Department of Energy toward solution of mankind's most pressing problem.

Aeronautical research and development is another area of direct benefit. NASA's role in this regard is that of pathfinder, pioneering technological innovations to

improve the current generation of aircraft and to lay the foundation for the more advanced airplaces of the future. This important work benefits the national economy by elevating the competitive posture of American plant builders in the international marketplace; it benefits those who fly by contributing to flight safety and performance; and it benefits the general public by improving the environmental characteristics of flight systems.

Finally, there is NASA's space science program, an area of direct benefit although the nature of the benefit is not readily apparent. Generally, space science expands our fund of knowledge about the intricate workings of the universe and this knowledge serves as the informational base upon which technology draws to bring forth practical applications.

To put spinoff in proper perspective, a prefacing section of this volume describes these areas of direct benefit and outlines NASA's mainline effort, the major programs which generate new technology that may later be applied to civil needs and conveniences via the spinoff process. The bulk of this publication focuses on spinoff benefits—what they are, and how they come about, and the extraordinary degree to which they pervade everyday life. The aim of Spinoff '78 is to heighten awareness of the benefit potential in secondary application of NASA-developed technology and thereby to inspire prospective users of this technology to take advantage of an important national resource. The ultimate goal is improvement of the technology transfer process, with attendant benefit to the U.S. economy, hence to the people of the United States who finance the technology investment.



Louis Mogavero, *Director*

Technology Utilization Division
Office of Space and Terrestrial Applications
National Aeronautics and Space Administration

January 1978

Spinoff '78 is the annual report of NASA's Technology Utilization Program, which is charged with promoting and stimulating the practical application of government-sponsored aerospace technology. The report is organized in three sections: 1. Aerospace Aims; 2. Technology Twice Used; and 3. Technology Utilization. Section 1 outlines NASA's major programs in space exploration, aeronautical research and technology application, and describes the potential benefits of a direct *nature that are accruing from these efforts. Section 2 contains a representative sampling of the* indirect *benefits resulting from the secondary use of aerospace technology in industry and the economy. Section 3 details the nationwide activities of the Technology Utilization Program in encouraging the broadest possible secondary use of new technology emerging from aerospace programs. The latter section also includes a list of regional NASA officials and others who can be contacted by those seeking NASA technical information or assistance.*

Spinoff 1978

an annual report

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A pictorial summary of NASA's major programs, their missions and goals, and the many ways in which they are producing direct benefits to the people of Earth

Aerospace Aims

8

NASA's Space Shuttle presents greater opportunity for Earth benefit through routine, economical access to space

Space Flight Comes Of Age

NASA's Kennedy Space Center is once again humming with activity. The Florida spaceport, launch site for the Apollo moon flights and subsequent manned missions, has been relatively quiet for three years. Now workmen are swarming over the huge Launch Complex 39, preparing it for another exciting chapter of space history.

A new era will begin next year with the first orbital flight of NASA's Space Shuttle, the reusable space transportation system that will significantly reduce costs and make access to space a matter of routine. The extraordinarily versatile Shuttle will give NASA an entirely new range of capability for pursuit of the Earth benefits that space offers.

Being developed under the direction of NASA's Johnson Space Center, the Shuttle will be rocket-launched like earlier spacecraft but with a difference: its two solid boosters are recoverable for re-use. The Orbiter, the manned segment of the Shuttle, will operate in space as a piloted maneuverable vehicle, then return to an airplane-like landing on Earth. When the Shuttle system is totally operational in the 1980s, there will be five Orbiters operating from Kennedy Space Center and from Vandenberg Air Force Base in California.

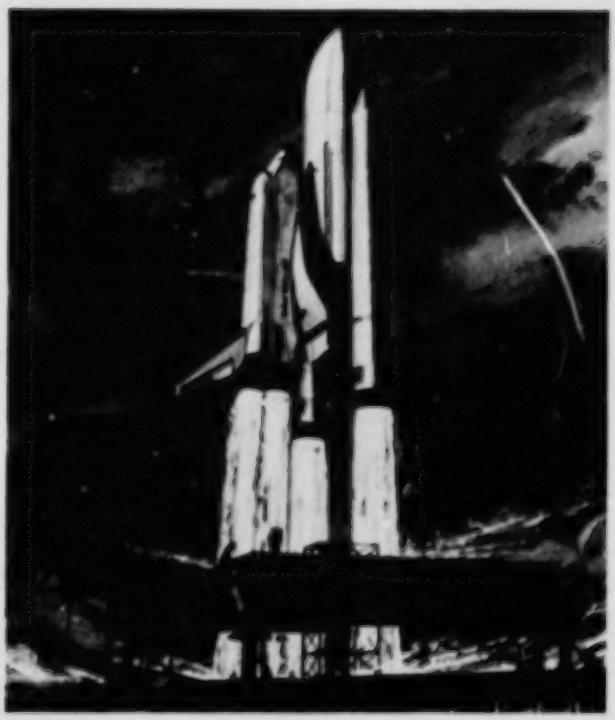
Space will no longer be the exclusive province of highly-trained astronauts. In addition to its crew of three, the Orbiter can accommodate up to four scientists or other specialists. Working without special space garb, they can perform experiments, study the heavens from a vantage point in space, or relay information about weather, agricultural and environmental conditions on Earth.

The Shuttle will deliver payloads to orbit, allow in-space repair of unmanned satellites, or bring spacecraft back to Earth for refurbishing work that cannot be accomplished in orbit. Satellites whose operating altitude is beyond the Shuttle's 600-mile capability will be propelled to higher orbits by a rocket booster carried aloft in the Orbiter's large cargo bay. In the same manner, interplanetary spacecraft can be launched into deep space trajectories.

Exciting new tasks hitherto considered impractical or overcostly become feasible with the Shuttle. It opens the door to in-orbit manufacturing of certain products which are better produced in space, or to the assembly of habitable space settlements from Shuttle-delivered "building blocks." A potential benefit of sweeping dimension is a network of Shuttle-erected orbiting power stations capable of converting the sun's energy into unlimited supplies of electricity for Earth use.

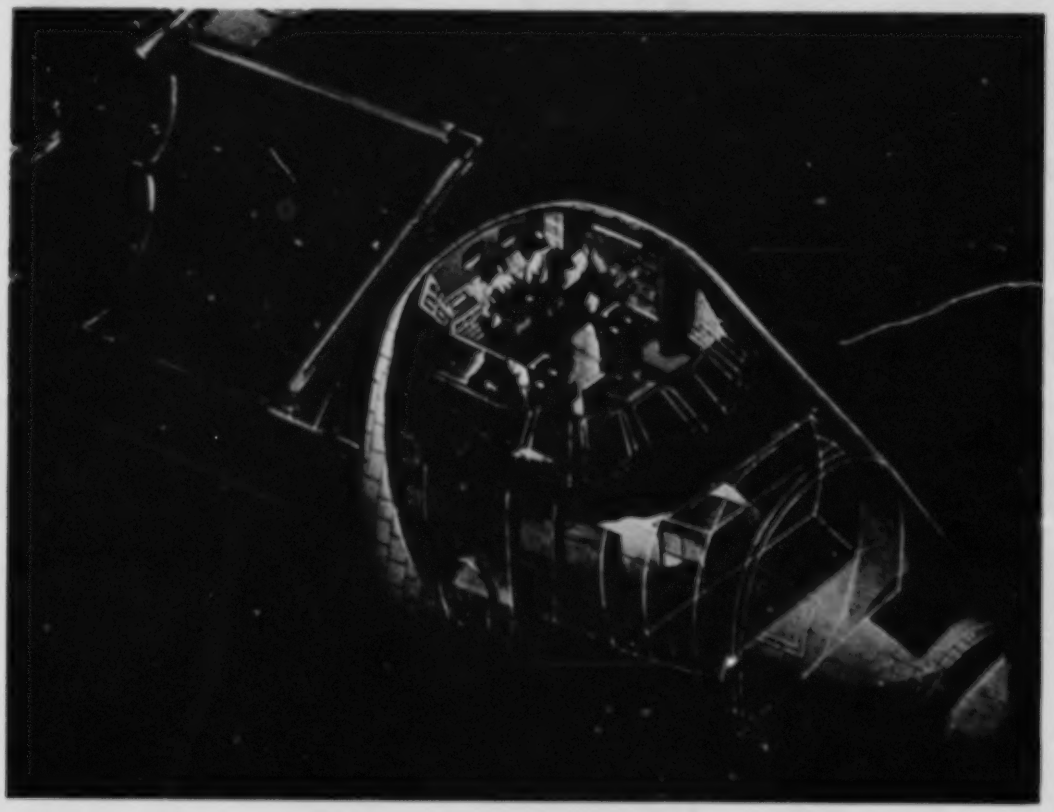
Economy is the Shuttle's keynote. Reuse of both Orbiter and its boosters eliminates costly one-shot launch vehicles. Orbital repair or retrieval of satellites extends their useful lives and saves replacement costs. And since the Orbiter lands routinely at Earth shuttleports, there is no requirement for the expensive sea recovery forces employed in the Mercury, Gemini and Apollo programs. Overall cost reductions are estimated at a billion dollars yearly, money which can be diverted to a broader quest of Earth benefit.

Flight of the Enterprise Pictured on its first free flight last summer, the Shuttle Orbiter *Enterprise* successfully concluded the initial phase of its test program in 1977. For checkout of its aerodynamic control and landing characteristics, *Enterprise* was piggybacked to high altitude by a modified Boeing 747, then released for glide landings at Dryden Flight Research Center. The Orbiter and other elements of the Space Shuttle system are now undergoing extensive ground testing.

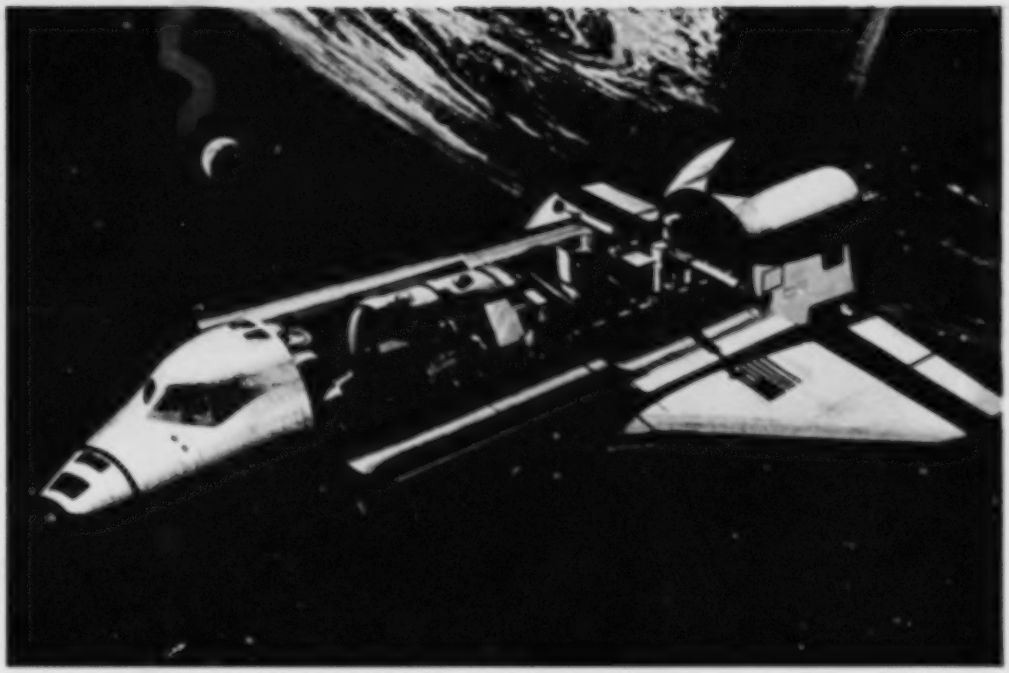


Shuttle Blast-off This conceptual illustration will become reality next year with the inauguration of Shuttle manned orbital flights. The Shuttle is launched by a combined thrust of more than 6,500,000 pounds, produced by the Orbiter's three main engines and two large solid rocket boosters. The boosters, being developed under the supervision of Marshall Space Flight Center, separate at a predetermined point, descend by parachute to an ocean landing, and are recovered for reuse. The huge central fuel tank feeds the Orbiter's engines during the boost phase, then is jettisoned and not recovered. Using its own internal fuel for maneuvering, the Orbiter operates in space for as long as 30 days and returns to an Earth landing. In about two weeks—refurbishing time—it is ready for another mission. Following six orbital proof flights, the Shuttle is expected to go into operational service in 1980.

Delivery to Orbit A major use of the Space Shuttle will be delivery of satellites to orbit, virtually eliminating the need for single-use launch vehicles. In its spacious cargo bay, the Shuttle Orbiter can carry one large spacecraft or as many as five smaller satellites. Satellites are extracted from the cargo bay by a remotely operated "manipulator," a long robot arm which releases the satellite a safe distance from the Orbiter. Adjustments to the satellite's orbital path can be made by radio signals triggered by the Orbiter's crew. The cutaway drawing shows crew positions on a delivery mission. Looking aft, the crewman at right rear is the payload handler. His station contains displays and controls for opening and closing the cargo bay doors and for operating the robot arm. He has direct visual contact through the aft-facing window and he is further aided by two video monitors which present views from two TV cameras in the cargo bay. The lower deck houses the environmental control system and other avionics equipment, the galley, passenger seats, living facilities and an airlock which provides access to the cargo bay.

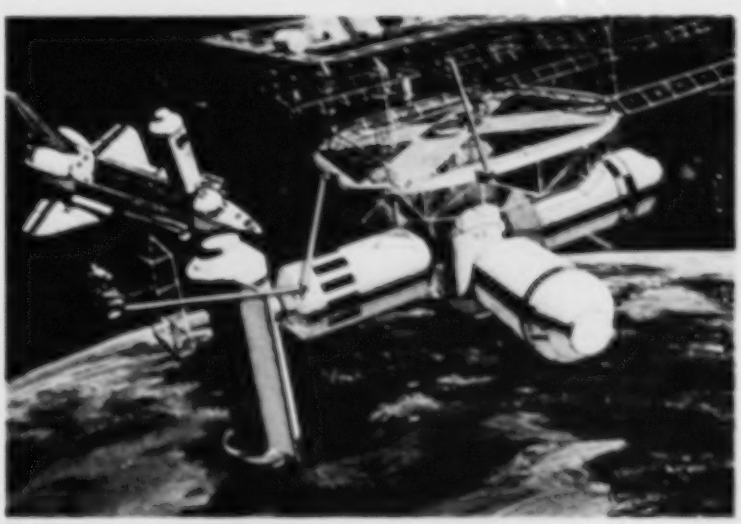


Satellite Servicing An important feature of the Space Shuttle is the operational economy it offers in delivery and maintenance of unmanned satellites. In the photo at right, a robot arm operated by a crew member "captures" a satellite in need of servicing. Certain repairs can be effected in orbit; the satellite is then released to continue its work. For refurbishing which cannot be accomplished in space, the captured satellite is stowed in the Orbiter's payload bay and returned to Earth.



Spacelab A pressurized flying laboratory that fits into the Orbiter's payload bay. Spacelab provides non-astronaut specialists the opportunity to experiment in the weightless environment of space for extended periods. Developed on a modular basis, Spacelab's equipment can be changed to meet the specific needs of a variety of missions—for example, Earth surveys, astronomy, space manufacturing research, or life science studies of man and other living things under weightless conditions. Spacelab is a prime example of NASA's commitment to promoting international space cooperation. It is being financed and developed by 10 member nations of the European Space Agency, whose activities are being coordinated by Marshall Space Flight Center. Spacelab is available to all nations and initial participation will involve investigators from 15 countries. First flights are planned for 1981.

Space Settlement Shuttle versatility makes feasible that long-considered feature of science fiction, the human-habitable space settlement. The illustration shows how Shuttle-delivered modules can be fitted together to create large orbiting structures. The station thus assembled would provide a permanent facility for space research, Earth observations and a variety of beneficial purposes. A far-reaching prospect, to be pioneered in Spacelab flights, is in-space processing and manufacturing. Biomedical processing in the stable, gravity-free orbital environment offers opportunities for purifying vaccines by removal of impurities that cause undesirable side effects, or for isolating specific cells and antibodies for treatment of disease. In industrial technology applications, zero gravity lends itself to manufacture of new alloys and composite materials that are uniquely strong, light-weight and temperature-resistant. Other applications include production of very large, high-purity crystals for electronic systems, and creation of pure glass, free of container contamination, for optical, laser and electronic uses.



Tomorrow's safer, cleaner, quieter, less fuel-thirsty and better performing airplanes are taking shape today in NASA's aeronautical research facilities

Trailblazing Future Flight

More than 60 years ago, Congress created NASA's predecessor agency, the National Advisory Committee for Aeronautics, "to supervise and direct the scientific study of the problems of flight with a view to their practical solution." NACA, and later NASA, have responded to that mandate, producing a lengthy succession of important aeronautical technologies that have established the United States as world leader in aviation.

NASA's role in aeronautics remains largely unchanged from the Congressional directive of 1915. The agency's job is to probe the frontiers of atmospheric flight and to develop advanced technology for civil and military aircraft, with particular emphasis on solution of aviation problems. This broad and expanding effort provides direct benefit in a number of ways. It contributes to national security; it helps manufacturers produce more efficient commercial aircraft, with attendant benefit to the U.S. economy through aircraft sales; it improves flight safety for all airplane users; it helps trim aircraft operating costs to the advantage of operator, passenger and shipper; and it eases the environmental impact of flight by reducing noise and pollutants.

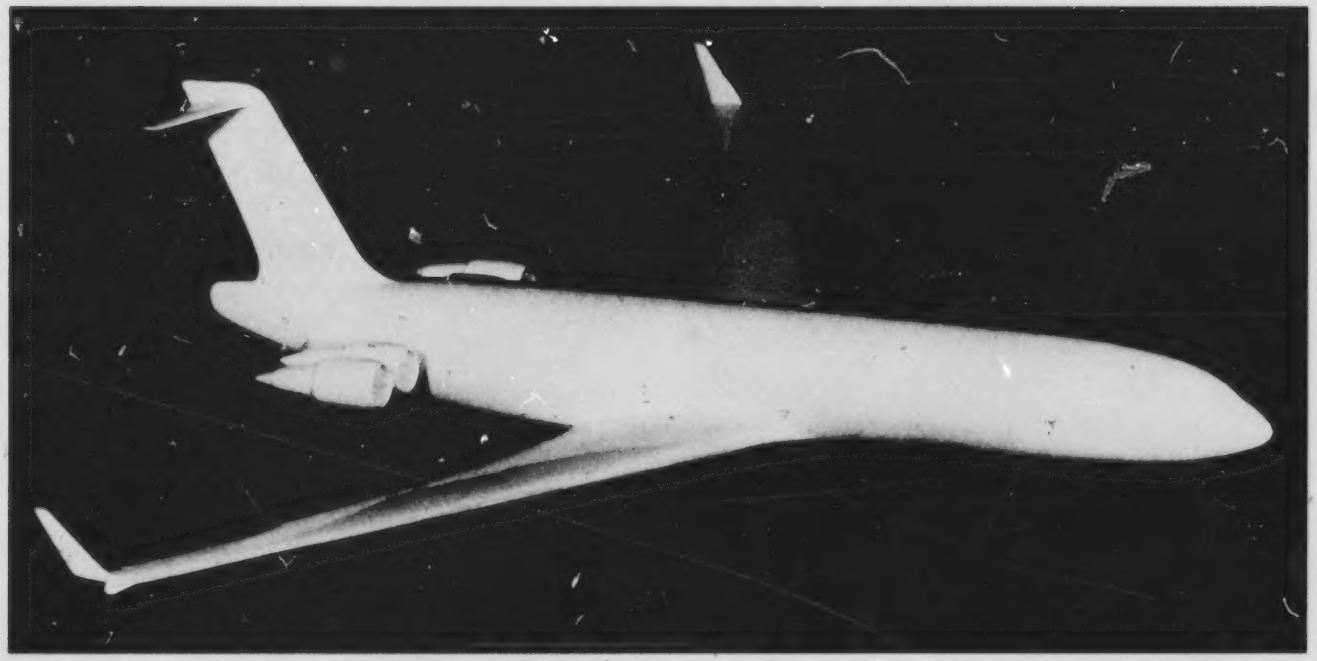
NASA's aeronautical program involves two general areas of research. Looking well into the future, NASA anticipates tomorrow's needs and develops applicable technology. Researchers are pursuing technological advances in vertical and short take-off and landing aircraft to reduce the need for long runways; efficient, environmentally acceptable and economically viable supersonic cruise transports; cargo aircraft of immense capacity that will dwarf today's giants; and hypersonic cruise transports of the 21st century.

In the other general area of effort, NASA seeks new technology for airplanes already flying or those that will be forthcoming in the not-distant future. Principal focus is on aircraft energy efficiency to curb airplane fuel appetites. This work embraces not only the obvious field of engine research, but also improved aerodynamic shapes, computerized flight control systems, and lighter aircraft structures, all of which influence fuel expenditure. NASA has identified technologies which collectively could cut fuel consumption in half, a potential of enormous economic significance. Closely related is "clean and quiet" engine research, wherein NASA continues to make a concerted effort to improve the environmental characteristics of current and future aircraft.

Most importantly, NASA is constantly striving to develop technology for safer airplanes of all types, from the private light-plane to the large commercial airliner. Some examples of safety-enhancing investigation include fire-resistant materials research; collision avoidance research; studying techniques for warning pilots of potentially troublesome clear air turbulence; conducting lightplane crash tests with an eye toward greater passenger protection; and development of accident prevention measures through aviation safety incident reporting.

Other investigative efforts include research on airfoils to improve aircraft performance, looking into ways to increase the efficiency of crop dusters, and development and test of advance helicopter rotor systems.

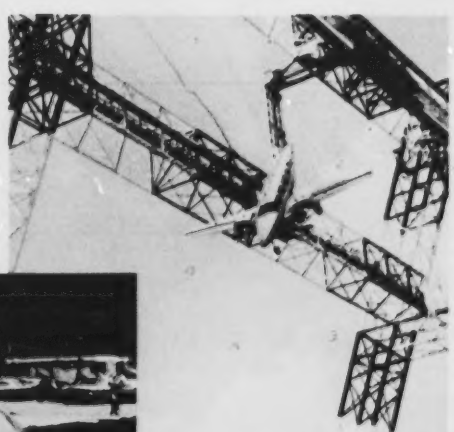
Fuel Saving Research Tomorrow's airliner may have a different look, perhaps like the model pictured, as a result of NASA's Aircraft Energy Efficiency program. One way to cut fuel consumption is to improve aerodynamics, reducing air resistance and saving fuel because the engine need not work as hard. So NASA is developing a family of new wings and other aerodynamic features, for application to small aircraft as well as airline transports. Obviously, a lighter airplane also eases engine workload; researchers are working on new structural materials that are not only lighter but stronger than those they will replace. Also being explored are varieties of ways to make the engine itself more fuel efficient. Through these and other approaches, NASA hopes to provide the technology to cut fuel consumption of future civil transport aircraft in half.

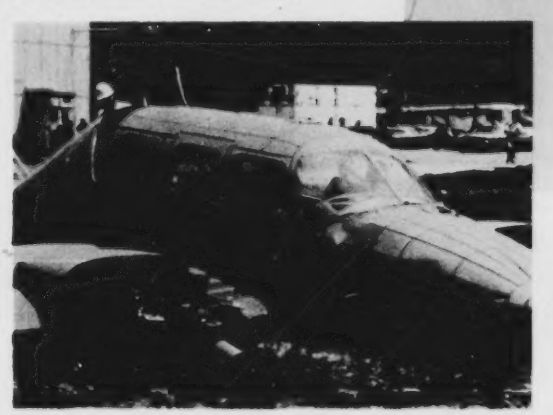


Clean And Quiet This unique airplane is a half-size wind tunnel model of the Quiet Short-haul Research Aircraft (QSRA), a modified medium transport featuring exceptionally low noise levels and the ability to operate from very short runways. Flight tests of the full-scale QSRA will pave the way for future civil use of clean and quiet short take-off and landing aircraft operating from airports close to cities. In related research, NASA is developing a Quiet, Clean Short-haul Experimental Engine and a Quiet, Clean General Aviation Turbofan engine.

Crop Spraying Research For agricultural aviation, NASA is taking a new look at the spray-plane with a view toward efficiency and better protection of both crops and the environment. Research aims at new technology for dispersal equipment and spraying accuracy, together with improvement of airplane characteristics for the special demands of agricultural flying.

Crashworthiness Tests In cooperation with the Federal Aviation Administration, NASA is conducting a crash research program for improved safety of general aviation, meaning all civil planes except commercial airliners. The objectives are to find out what happens to plane structures in accidents and to design better structures for greater safety of pilots and passengers.





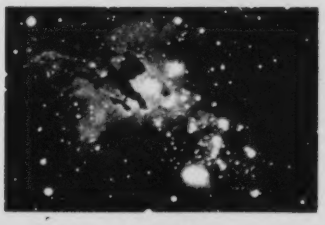
Tilt Rotor Airplane The tilt rotor type of airplane is considered a promising concept for future short-haul commercial transportation. NASA is investigating the concept in flights of the XV-15 Tilt Rotor Research Aircraft, a joint Army/NASA project. Helicopter-like rotors permit the craft to take off and land vertically. Once airborne, the rotors tilt forward to become propellers, allowing the plane to cruise at about 400 miles per hour.

HiMAT An important project in pioneering technology for future military aircraft is the Highly-Maneuverable Aircraft Technology program (HiMAT). Using wind tunnel models and unmanned remotely-piloted research vehicles, NASA is exploring various airplane configurations toward improving high-speed maneuverability. Photo shows a new HiMAT unmanned research craft which incorporates a number of advanced design features for far greater maneuverability than is currently attainable.

Supersonic Cruise Technology Existing SST's are not the last word in commercial transportation. There is predicted need for a larger, more economical and environmentally acceptable second generation SST, which could be flying in the 1990s. Toward that end, NASA is conducting research and developing technologies in the Supersonic Cruise Aircraft Research program. Emphasis is on a low-noise, reduced emissions engine that will operate efficiently at both subsonic and supersonic speeds. NASA is also studying materials, wind tunnel-testing new aerodynamic shapes, and investigating new manufacturing methods for forming supersonic transport structures.

NASA's space science program is producing a wealth of knowledge applicable to human benefit

Exploring The Cosmos



Last summer NASA launched two Voyager spacecraft on a journey to infinity. The automated probes will explore the great planets Jupiter, Saturn, and probably Uranus, then depart the solar system to cruise through interstellar space for perhaps millions of years.

Voyager is a milestone in NASA's systematic program of planetary exploration. It heralds greater emphasis on investigation of the outer planets—Jupiter, Saturn, Uranus, Neptune and Pluto—along with further probing of the inner planets—Mercury, Venus, Earth and Mars. From flight missions like Voyager and from other observations, NASA is assembling millions of individual bits of cosmic data into a vast informational mosaic. The ultimate goal is an understanding of the origin, evolution and intricate workings of our solar system and its individual planets.

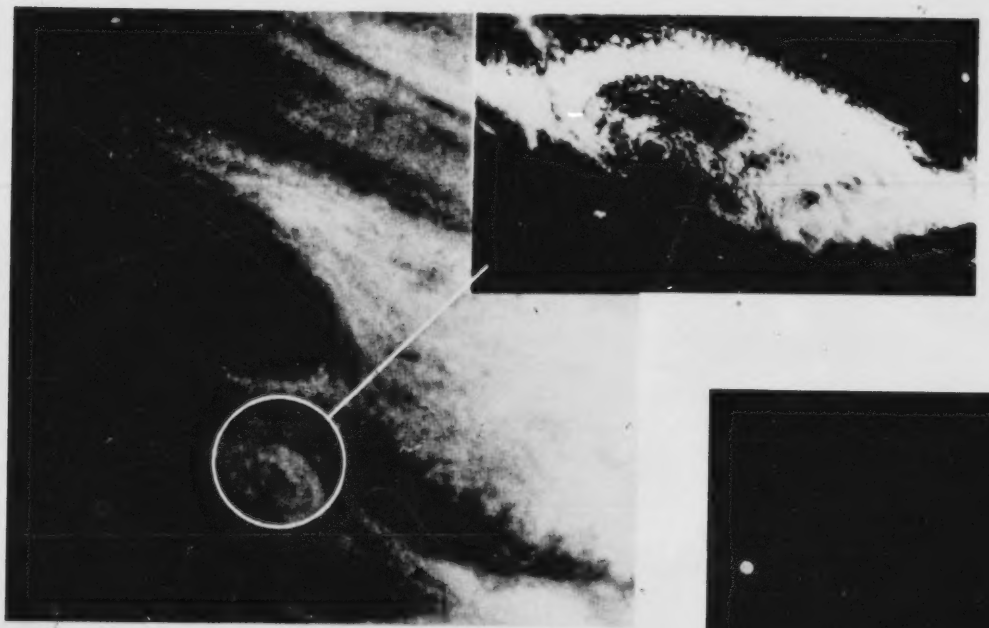
Planetary exploration is but one segment of NASA's comprehensive and carefully planned space science program. The agency is also conducting extensive investigation of Earth, its atmosphere, its moon, near-Earth space, the sun, the stars of our galaxy and those beyond. In life science research, NASA is studying the effects of the space environment on human and other organisms. Satellites and deep space probes are the most familiar tools of this broad effort, but NASA also employs non-orbiting sounding rockets, instrumented aircraft and balloons, optical and radio telescopes and a great variety of Earth-based equipment.

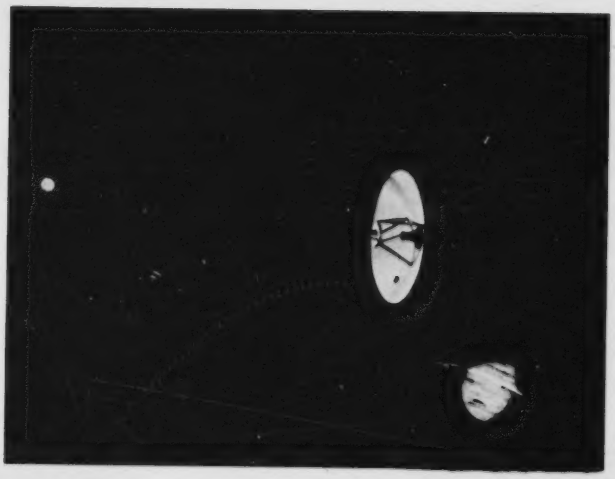
The purpose behind this immense scientific quest is the same as the motivation for NASA's other areas of research and development—the benefit of mankind. In space science, the benefits are less immediate and less apparent, but no less valuable to humanity's future. They are, in a word, knowledge—knowledge which is itself an invaluable resource and which becomes practical benefit when it is applied. Some of the knowledge will not find practical application in our lifetimes, but much of it will contribute to advancing technology.

The vital importance of technology to a civilization's progress is well established. Science shares that importance because it is technology's foundation, the well from which technology draws to produce new inventions. The information being acquired in the space program spans a wide spectrum of scientific disciplines. Thus, the storehouse of knowledge being developed is applicable not just to aerospace technology, but to many other avenues of mankind's advancement.

The goals of space science are many, but they have a common denominator—learning more about Earth. Through exploration of other bodies in the heavens, NASA is establishing a comparative base for our perceptions of Earth, limited until now because, as one scientist puts it, "we have been stuck on one planet." By comparing the characteristics of other planets with Earth's, we are gaining new perspective about our own habitat. Greater understanding of the complex forces that control Earth may bring the ability to manage them for broad and sweeping benefit to mankind.

Voyager Two Voyager spacecraft are off on an extensive reconnaissance of the solar system's outer planets. Their decade-long odyssey will enable them to return data on as many as 15 heavenly bodies, principally giant Jupiter and ringed Saturn. Arriving at Jupiter next year, they will make scientific measurements and take closeup pictures of the enormous planet and its moons. Then they will be directed to Saturn for similar investigations in 1980-81. If all goes well, one Voyager may be sent to Uranus, arriving about 1986 for the first close look at the seventh planet from the sun. After completing their planetary studies, the Voyagers will continue outward from the solar system to coast indefinitely through interstellar space. The upper photo depicts Voyager investigating a strange phenomenon called the "flux tube," caused by interaction between Jupiter and Io, one of Jupiter's largest moons. In the photo below, the circled area near Jupiter's red spot is a planetary turbulence system which may be similar in nature to Earth hurricanes like the one shown in the inset; the Voyagers will investigate Jupiter storm systems for comparison purposes. The photo at bottom right shows Voyager as it passes Saturn.

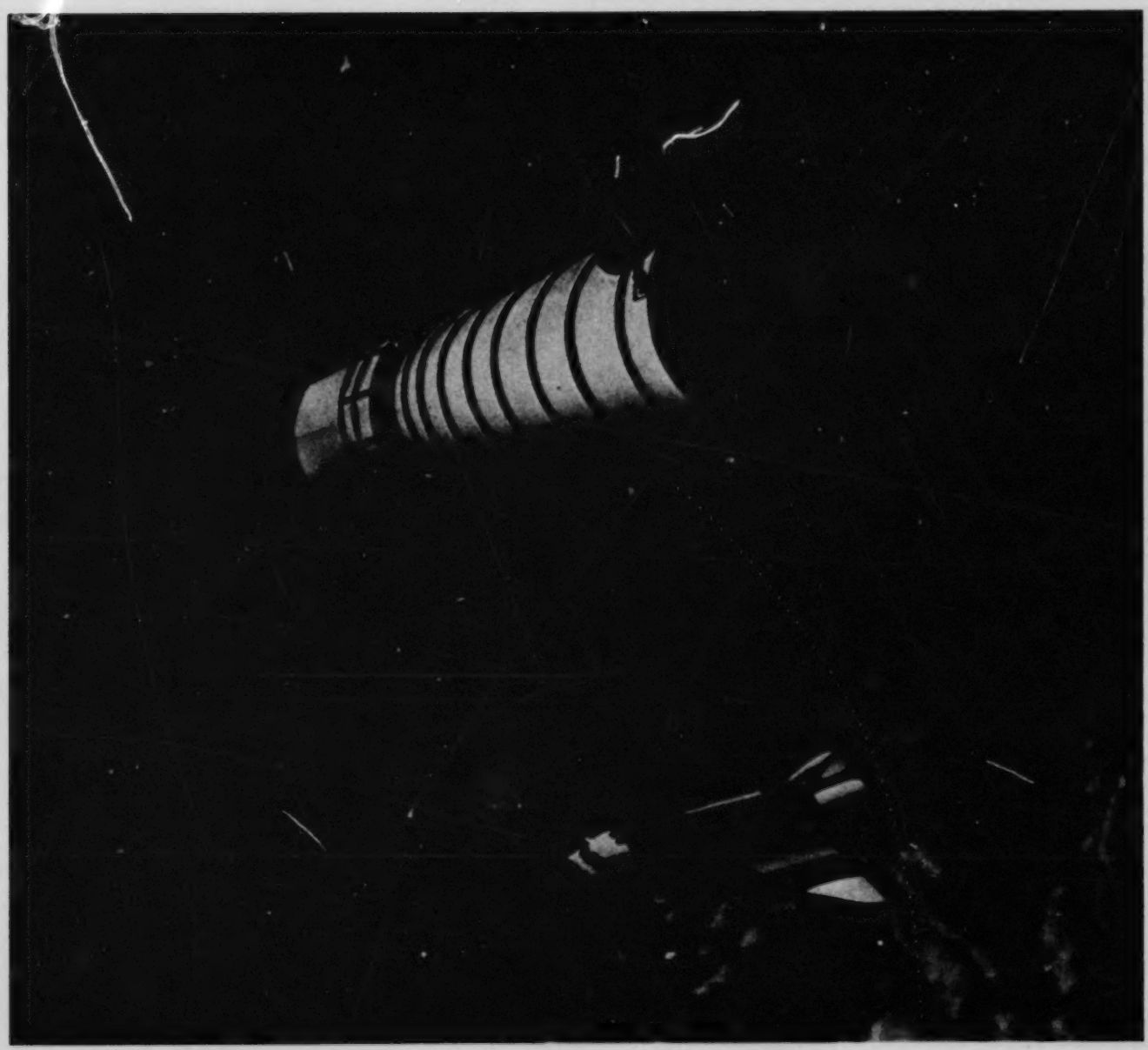


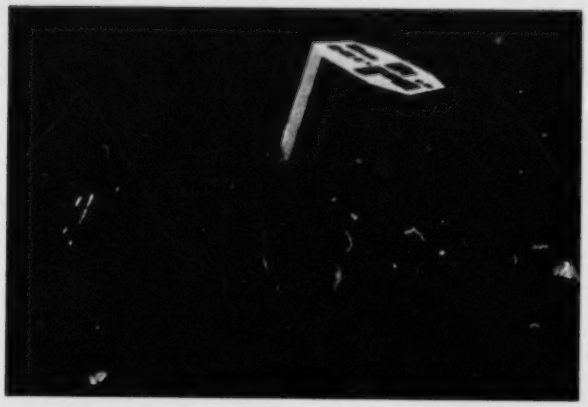


Pioneer Venus This year's planetary explorer is Pioneer Venus, to be launched in May or June for a December rendezvous with cloud-covered Venus. Pioneer Venus consists of two spacecraft. One will orbit the planet for at least one Venus year (243 days), examining the upper atmosphere and reporting the first detailed surface information. The other, pictured at left, will drop four probes through the atmosphere to make scientific measurements down to the surface. In many ways, Venus is the most earthlike planet and from this project NASA hopes to acquire data that may have direct application to atmospheric problems on Earth.

Probing the Superplanet Voyager's information about Jupiter will be amplified by the Jupiter Orbiter/Probe. Shuttle-launched in late 1981 or early 1982, the spacecraft will near Jupiter about a thousand days later. It will release a probe, shown in the photo above, that will descend through Jupiter's gaseous composition, reporting data for about half an hour before it is crushed by the tremendous pressure of the planet's lower atmosphere. The basic spacecraft will be "captured" by Jupiter's gravity, to become a new "moon" of the planet, which has 14 natural satellites. The orbiter will repeatedly photograph Jupiter and its moons, and its instruments will acquire additional data for relay to Earth. Close-up study of Jupiter, larger than all the other planets combined and markedly different from Earth, is expected to shed new light on the origin and evolution of the solar system— hence on Earth's own beginnings.

Space Telescope A project which has excited great interest among the scientific community is NASA's Space Telescope, a long-duration orbiting astronomical facility. Operating well above the layer of atmosphere that distorts Earth-based astronomy, the unmanned telescope will allow observations far deeper into space and supply far greater detail than has heretofore been possible. To be launched by the Space Shuttle in 1983, it will also be Shuttle-maintained; space-suited astronauts can replace instruments when necessary or the whole observatory can be brought back to Earth for refurbishment and redelivery to orbit.





New Sun Study The entirely gaseous sun undergoes periods of changing activity in the form of eruptions, particle discharges and radiation output. NASA wants to know more about this activity, particularly the massive disturbances known as solar flares and how they affect Earth's atmosphere. A new study of the sun will take place during the next period of maximum solar activity, 1979-1981. The principal research vehicle is the Solar Maximum Mission spacecraft, shown at left. To be launched late in 1979, it will investigate solar flares and other aspects of the sun-Earth relationship. Other spacecraft and ground-based observations will provide complementary data.

Non-Orbiting Research Vehicles Although spacecraft are the primary tools of space science, NASA employs non-orbiting systems such as instrumental balloons (photo above), aircraft and sounding rockets. Relatively inexpensive, these vehicles are particularly useful in upper atmosphere research, which has become increasingly important in recent years. An example of their practical utility is the current intensive study of Earth's ozone layer and whether it is adversely affected by pollutants such as aerosols, fertilizers and airplane exhausts.

NASA is applying its technical expertise in the national quest for new ways of producing and conserving energy

Accent On Energy

Of all the potential benefits of space, none is more exciting to an energy conscious world than the orbiting power station. A large structure, perhaps several miles long, the Satellite Power System would draw energy directly from the sun and beam it to Earth receivers, producing enough electricity to meet the needs of a large city. The energy supply would be inexhaustible and virtually free of the pollution caused by today's fuel-burning electrical power generators.

The concept has already progressed beyond the dream stage. First proposed a decade ago, it has been the subject of intensive study in recent years and is considered entirely feasible by the collaborating agencies—NASA and the Department of Energy. Although the technology advancement needed is of enormous dimension, experts feel that the initial space-based power station could be operating in less than 20 years. One estimate holds that, by the year 2030, there could be 100 or more satellites in orbit, generating a significant portion of the nation's power requirement.

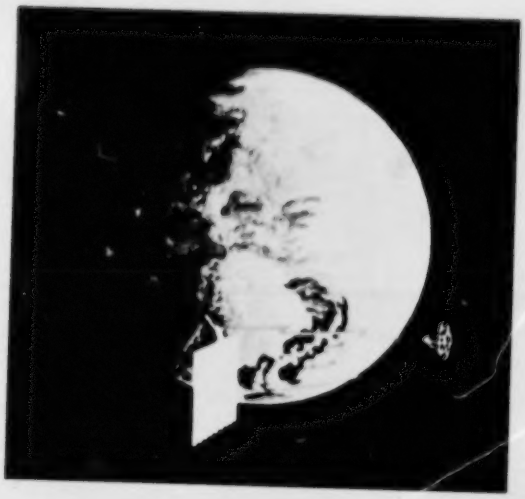
The Satellite Power System is the most dramatic projected advance in a relatively new area of NASA endeavor: development of technology to meet future Earth energy needs and to alleviate dependence on fossil fuel power. In addition to investigating ways whereby space systems may offer utility, NASA is applying its technical talents in support of Department of Energy programs and those of other government organizations, such as the Department of the Interior. In most of its energy-related activity, NASA's role is that of contractor to the other agencies, conducting assigned development projects on a reimbursable basis.

NASA has special capabilities for this work. Since the start of the Space Age, the agency has been engaged in development of energy systems for spacecraft—solar cell arrays, for example, which supply electrical power for unmanned satellites, and fuel cell powerplants for the greater electrical demands of manned spacecraft. NASA also draws upon its experience in such areas of aeronautical research as computer design, engines, propellers and rotor blades, fuels, lubricants, seals and bearings. This background provides a technology base for improving efficiency and reducing fuel consumption of non-aerospace machines. Additionally, NASA's aeronautical and space programs have produced personnel with expertise in an exceptionally broad range of scientific, technological and management disciplines. Thus, the agency can assemble teams of highly-skilled technologists whose collective knowledge can be brought to bear on a specific assignment.

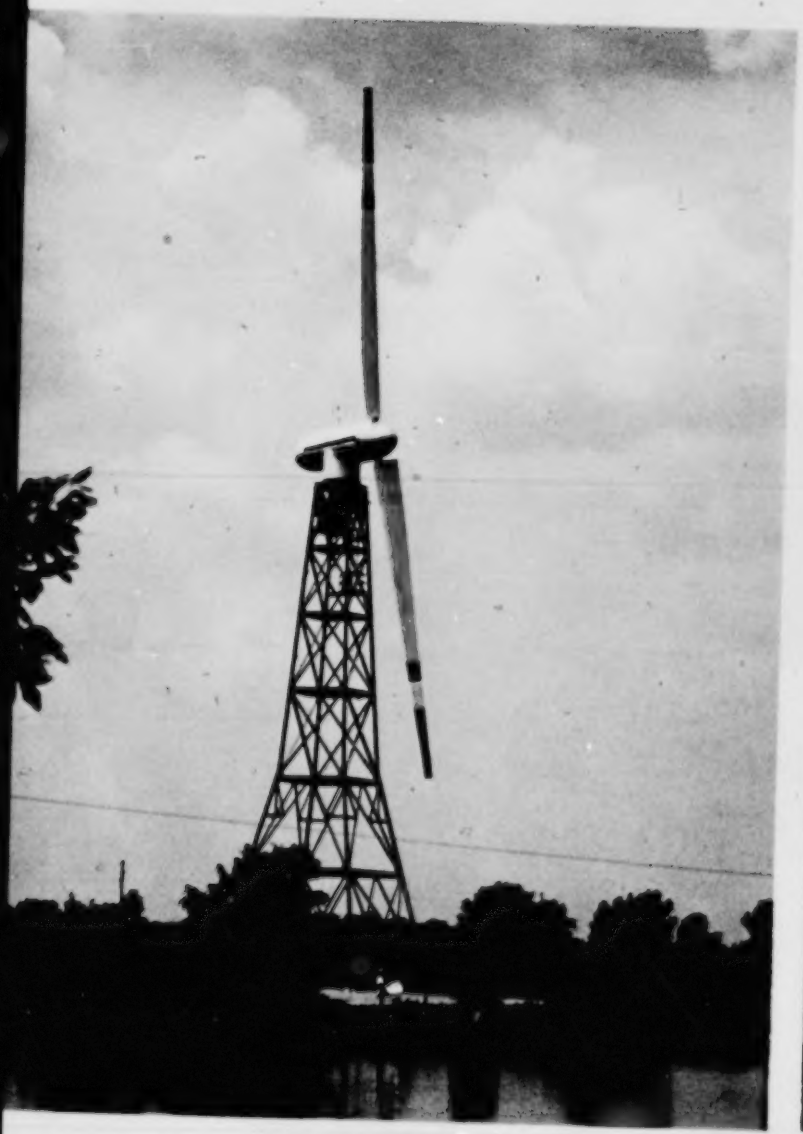
One example of NASA's work is finding new and more efficient ways to store excess energy for later use. In many applications, energy is produced and utilized as heat, so NASA's primary emphasis is on investigating heat storage mediums such as salt beds, rock beds and underground hot water tanks; stored heat can be extracted from these mediums and used as energy. Successful operation of energy storage systems in transportation, power generating facilities, industrial plants and commercial buildings can provide significant savings in capital equipment. NASA serves as project manager for the Department of Energy in high temperature thermal energy storage research.

Other examples of a broad and varied NASA energy program include development and demonstration of reliable, commercially acceptable solar heating and cooling equipment; advanced technology for methods of converting sun heat and wind energy to electricity; ways of increasing production in coal mining operations; measures to reduce the energy demands of industrial turbines; and new types of auto engines that could contribute substantially to fuel conservation.

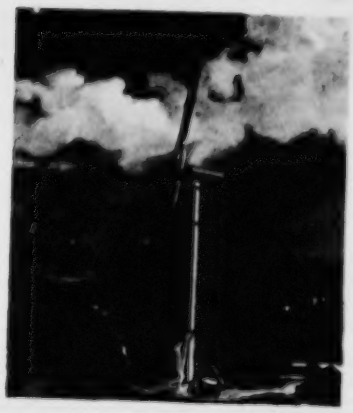
From this activity the nation is getting a return on its investment in aerospace technology. And there is bonus value in that new skills acquired in energy research will broaden NASA's capability for future aviation and space developments.



Satellite Power System An exciting possibility that promises enormous benefit is the Satellite Power System, which would produce enough power to serve a large city by transforming abundant solar energy into electricity. The huge orbiting station, several miles in length, would be assembled in space from equipment delivered to orbit by the Space Shuttle. The electricity generated would be converted to microwaves and transmitted to Earth. At Earth receivers, microwave energy would be reconverted to electricity for use by consumers. Studies indicate the concept is feasible and the first operational power station could be in orbit before the turn of the century. An interim step, illustrated in the artist's drawing, is an initial demonstration system to validate the space solar power concept.



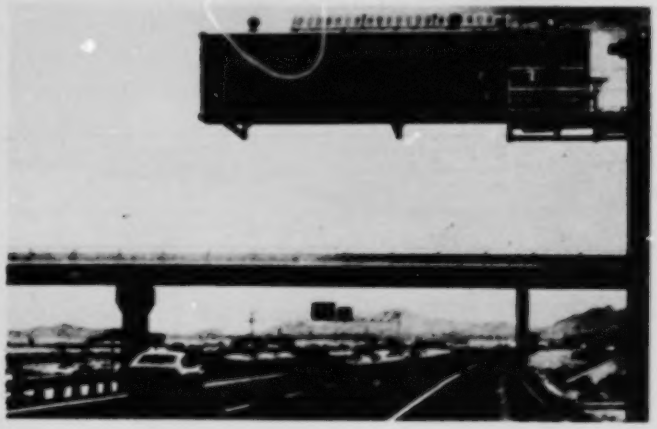
Harnessing The Wind NASA is assisting the Department of Energy in development of modern, efficient windmills. Wind force is used to spin a large, propeller-like rotor which drives an electrical generator; the electricity thus produced is fed to a local utility for public consumption. The 125-foot diameter wind turbo-generator shown at left is a NASA experimental system located at Plum Brook, Ohio, one of four similar machines now operating or planned to be operational this year. It has successfully demonstrated ability to create electrical energy in relatively small amounts (100 kilowatts). Larger machines are planned, since research indicates that the cost of wind energy drops as size increases. Two new windmills, to be erected at utility sites late this year and early in 1979, have rotors spanning 200 feet; each has a design capacity of 2,000 kilowatts, enough for the electrical needs of several hundred homes. In development for later use is a 300-foot diameter system, pictured below, capable of producing 2,500 kilowatts.

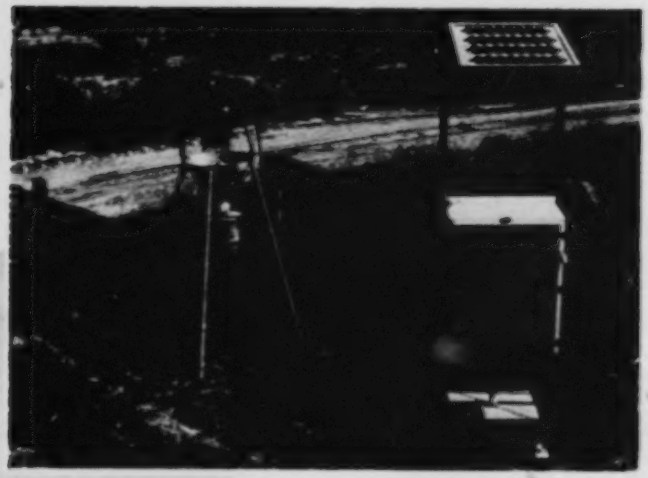


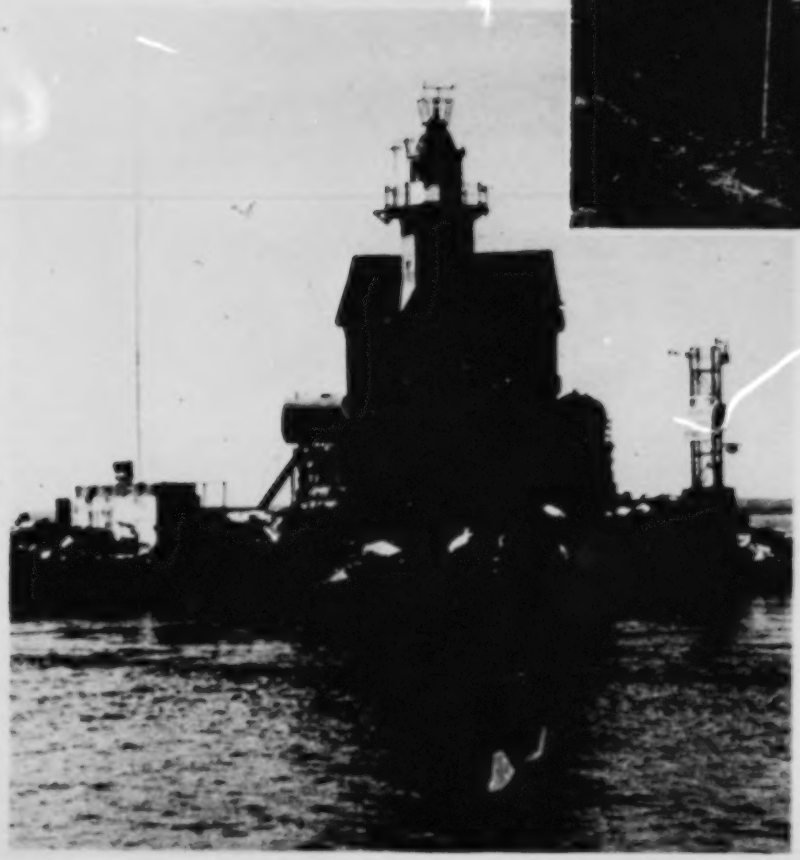
Solar Heating And Cooling This solar heated office building in Huntsville, Alabama is one of a number of installations in various climatic zones wherein NASA-developed solar energy hardware is being evaluated. NASA is helping the Department of Energy promote the use of solar energy in homes and commercial buildings. NASA's principal job is developing and demonstrating solar heating and cooling equipment which will perform more efficiently with good reliability at reasonable cost. NASA is also assisting the Department of Energy in the Commercial Demonstration Program, under which more than 100 buildings have been selected for installation and evaluation of solar systems.

Electricity From Sunlight Solar cells convert sunlight into electrical energy in a process called "photovoltaic conversion." Initially used to provide power for satellites, solar cells are now being investigated for use in Earth applications. NASA's Jet Propulsion Laboratory (JPL) and Lewis Research Center are supporting the Department of Energy's Photovoltaic Program. JPL manages a technology advancement project which is directed toward reducing cost and extending the lifetimes of solar cell arrays.

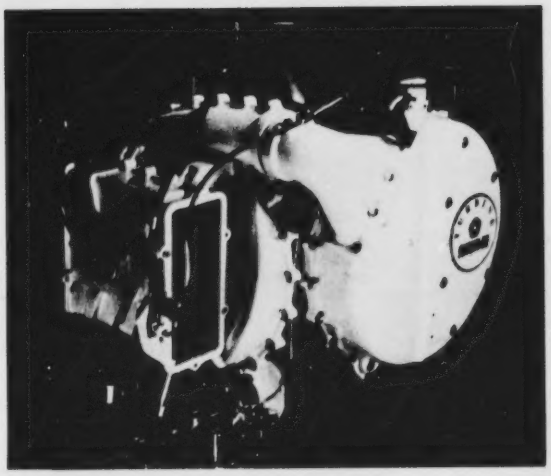
Lewis Research Center is working to stimulate a market for solar cells by installing cost-effective applications which demonstrate the advantages of this method of power generation. Examples include: below left, a highway dust warning sign near Casa Grande, Arizona, powered by the solar cells shown atop the sign; below, an insect survey and control trap near College Station, Texas; bottom left, a remote weather station at Stratford Shoals, Long Island, with the solar array at right. Lewis is also conducting tests and evaluations to determine solar cell operating characteristics and to develop standard measurement procedures. The long range aim is development of practical, cost-effective, multi-million watt public use solar cell systems. Before that can happen, major cost reductions are essential. Cost is now about $15 per watt; the Department of Energy's research target is 50 cents a watt by 1986.

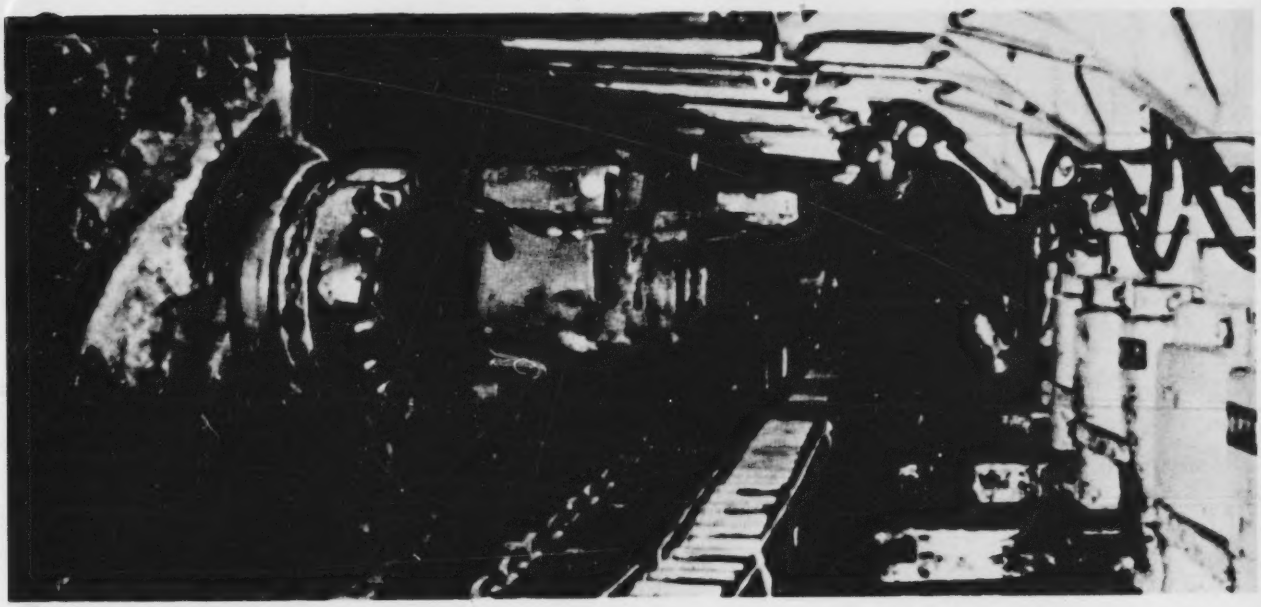






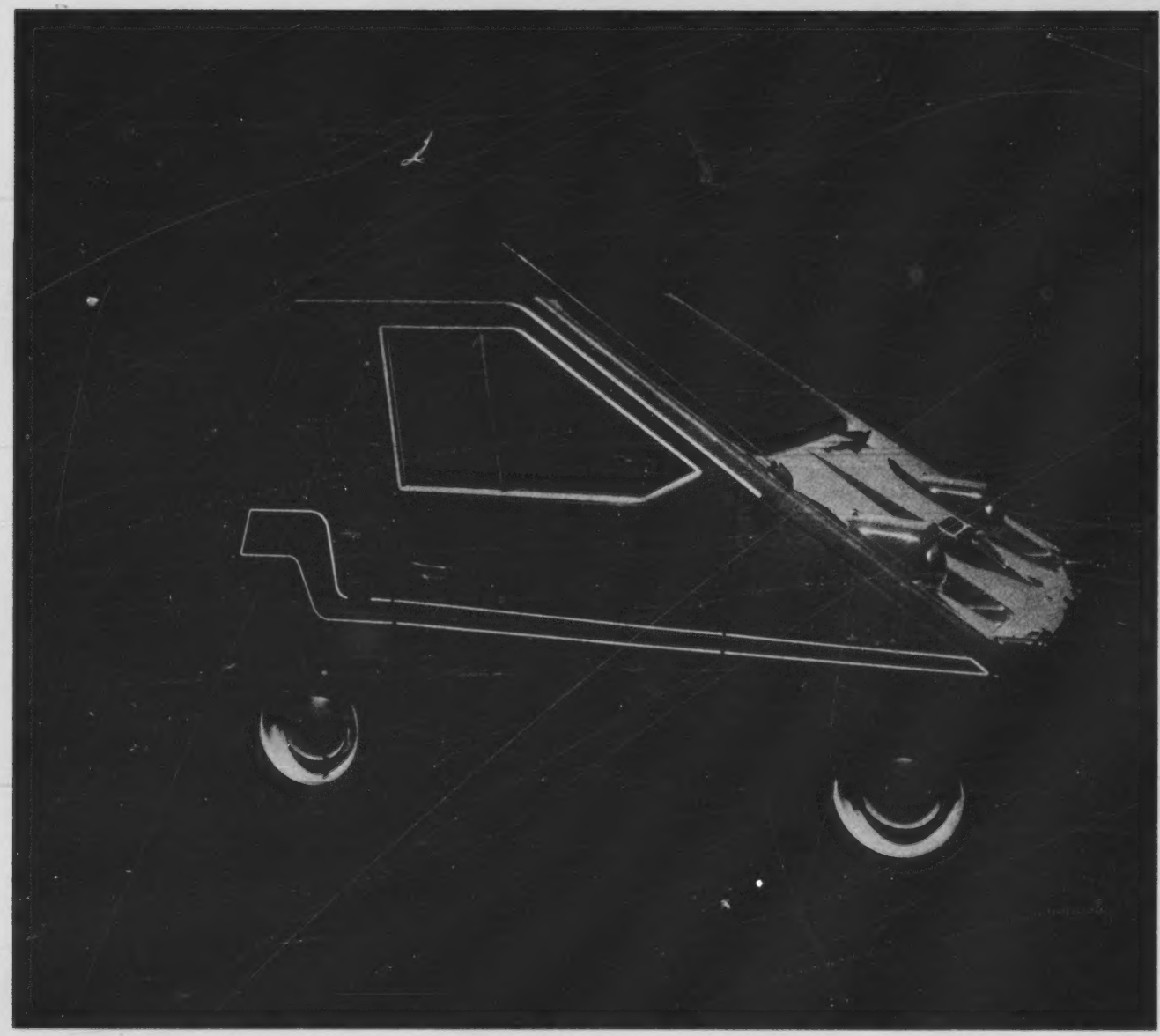
Auto Turbines The photo shows an automobile turbine engine developed by NASA's Lewis Research Laboratory in cooperation with an auto manufacturer. The turbine engine has long been considered for automotive use. NASA is conducting a program for the Department of Energy that may hasten its debut as a practical auto engine and provide significant national benefit in energy conservation and pollution reduction. NASA is developing technology for an auto turbine that would emit less pollutants, burn a variety of different fuels and most importantly, offer fuel economy 20-30 percent better than comparable internal combustion engines. A longer range goal is an advanced turbine featuring 50-60 percent better fuel consumption.





Coal Mining Research Working with the Department of the Interior's Bureau of Mines, NASA is seeking to improve underground coal mining operations by developing a guidance and control system for automating the longwall shearer (photo) which grinds coal from the wall or face of a coal seam. Currently, significant amounts of coal are left in the ground because longwall shearer operators do not cut to the extreme edges of the seam, for fear of breaking into surrounding rock or shale. Additionally, the cutting operation is a slow process because coal dust obscures visibility and makes it difficult to guide the cutting drums. An automated guidance and control system would offer multiple advantages: it would help conserve coal resources by allowing removal of virtually all the coal in the seam; its much faster cutting rate would increase annual production by millions of tons; it would reduce wear on the machine's cutters and minimize maintenance; and it would improve coal quality and miner safety. An initial step involves development of sensors, called Coal Interface Detectors, for determining the exact boundaries between coal and rock, information needed to guide the cutting drums. Evaluations by NASA's Marshall Space Flight Center have indicated the potential suitability of a system using such sensory techniques as gamma rays, radar beams, impact devices and reflected light. The next step, now under way, is development of the guidance and control system; Marshall engineers are applying technology originally developed for the Lunar Roving Vehicle used on Apollo moon explorations.

Electric Vehicles The auto pictured is one of a number of battery-powered electric vehicles being developed as a measure to reduce U.S. petroleum imports and curb automotive pollution. This electric car uses nickel-zinc batteries, adapted from space technology, which offer double the range of conventional lead-acid batteries. In support of the Department of Energy's electric vehicle program, NASA is handling road testing and evaluation of electrocars and also conducting research and development on both vehicles and propulsion systems.



NASA technology directly applied to societal needs is producing a bountiful harvest of public benefit

Putting Technology To Work

When an airplane goes down in a remote area, or when a ship encounters trouble on the high seas, radio beacons are triggered automatically to send out distress signals. But there is little assurance that anyone will respond to the call for help, because there is no adequate method of monitoring the signals and locating their source. As a result, many lives are jeopardized annually in aircraft and ship emergencies.

Aerospace technology offers an answer to this critical problem. In collaboration with the Canadian government, NASA has started development of a spaceborne system for quick detection and location of distress signals, a boon to search and rescue operations that will vastly increase the probability of saving lives.

The Satellite Search and Rescue System is the latest example of NASA's applications program, wherein aerospace technology is being addressed to society's needs. This program originated almost two decades ago when NASA pioneered development of communications and weather satellites, improved versions of which are now operating routinely and providing practical benefit of great value.

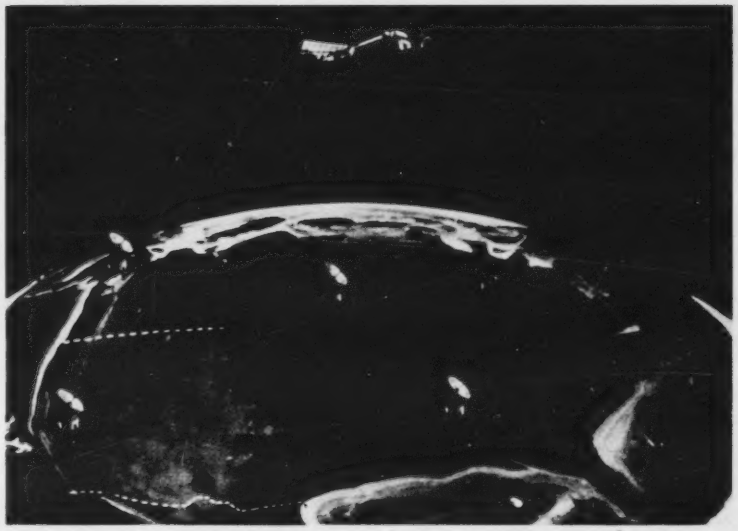
NASA is still developing advanced technology for communications and meteorological satellites, but the principal thrust of today's applications effort is toward better management of natural resources by means of space-derived information. The primary tool is Landsat, an Earth survey satellite whose sensors detect light waves reflected from Earth for translation into images that allow analysts to view the surface of the globe in new perspective. Landsat makes it possible to look at very large portions of Earth at one time, to study Earth features that cannot be discerned by the human eye and, through repetitive imaging, to monitor changing Earth conditions over a period of time. These capabilities offer a wide range of beneficial applications in such areas as agriculture, water management, mineral and petroleum exploration, land use assessment and world mapping. Three Landsats now in orbit are demonstrating the potential and paving the way for operational systems in the 1980s that will provide sweeping economic benefit.

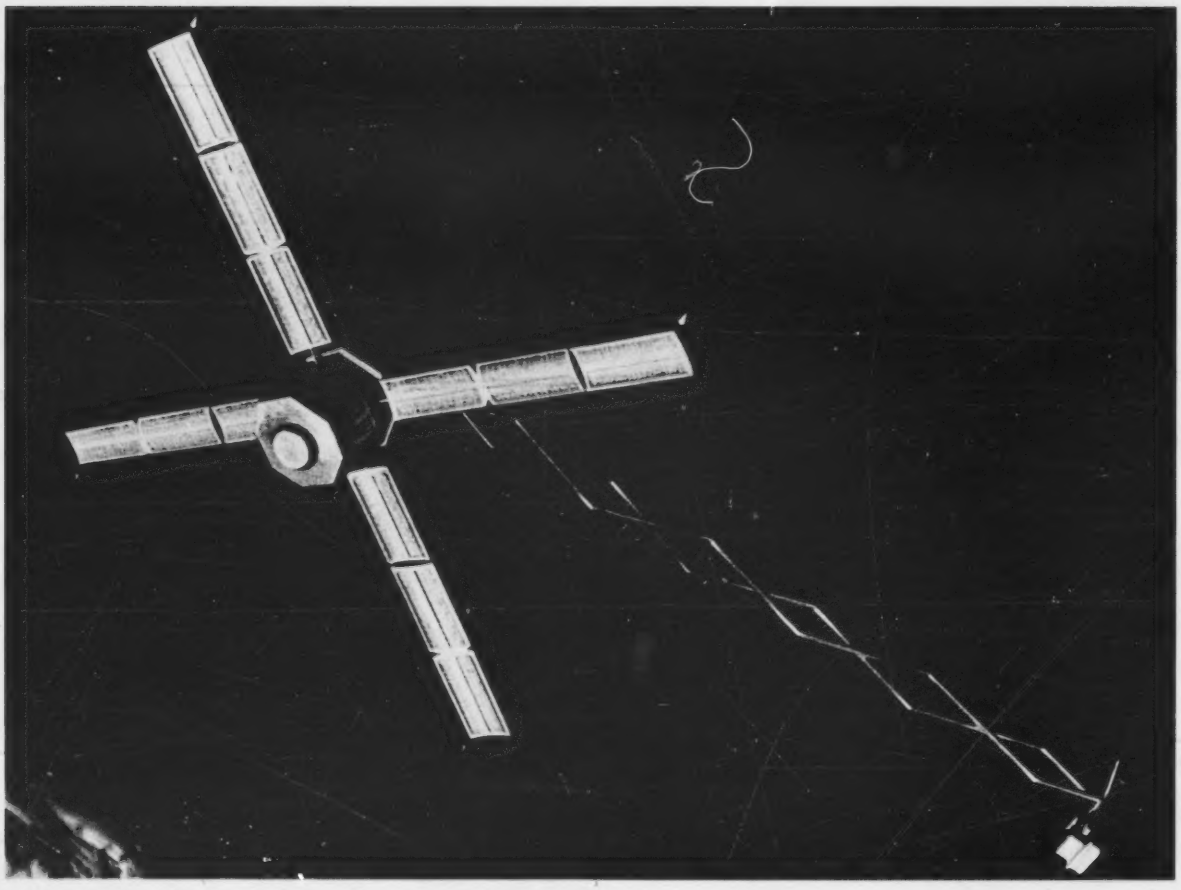
There are several other types of applications satellites. Already in orbit or scheduled for near-future launch are systems designed for such needs as improved communications for public service; monitoring and forecasting changing ocean conditions for the benefit of shipping, fishing and oil industries; and providing information on stratospheric pollutants and other environmental circumstances.

In addition, NASA is conducting applications programs of a non-space nature. One project, for example, involves a new wastewater treatment process that yields clean water at significantly reduced cost. Another employs ground-based laser radar to determine the spread of polluting particles exhausted from industrial smokestacks. A third is the use of computerized image enhancement techniques, developed for planetary explorers like Viking and Voyager, to improve detail in undersea photographs; the enhancement process produces visible features from apparently washed-out film.

These satellite and non-space innovations represent only a few of many direct applications. Already the dividends have reached major proportions but tomorrow's operational systems promise a dramatic expansion of direct benefit to the peoples of Earth.

Satellite Search and Rescue A NASA development with life-saving potential is the Satellite Search and Rescue System, a method of monitoring and locating distress signals from downed aircraft and troubled ships. The system is a radio package to be carried by operational satellites of the national meteorological satellite network. When the spaceborne package picks up a beacon signal, it measures direction of the source and relays the information to a Rescue Coordination Center, enabling the center to compute the beacon's location for guidance of search and rescue craft. The system will begin service in 1982.

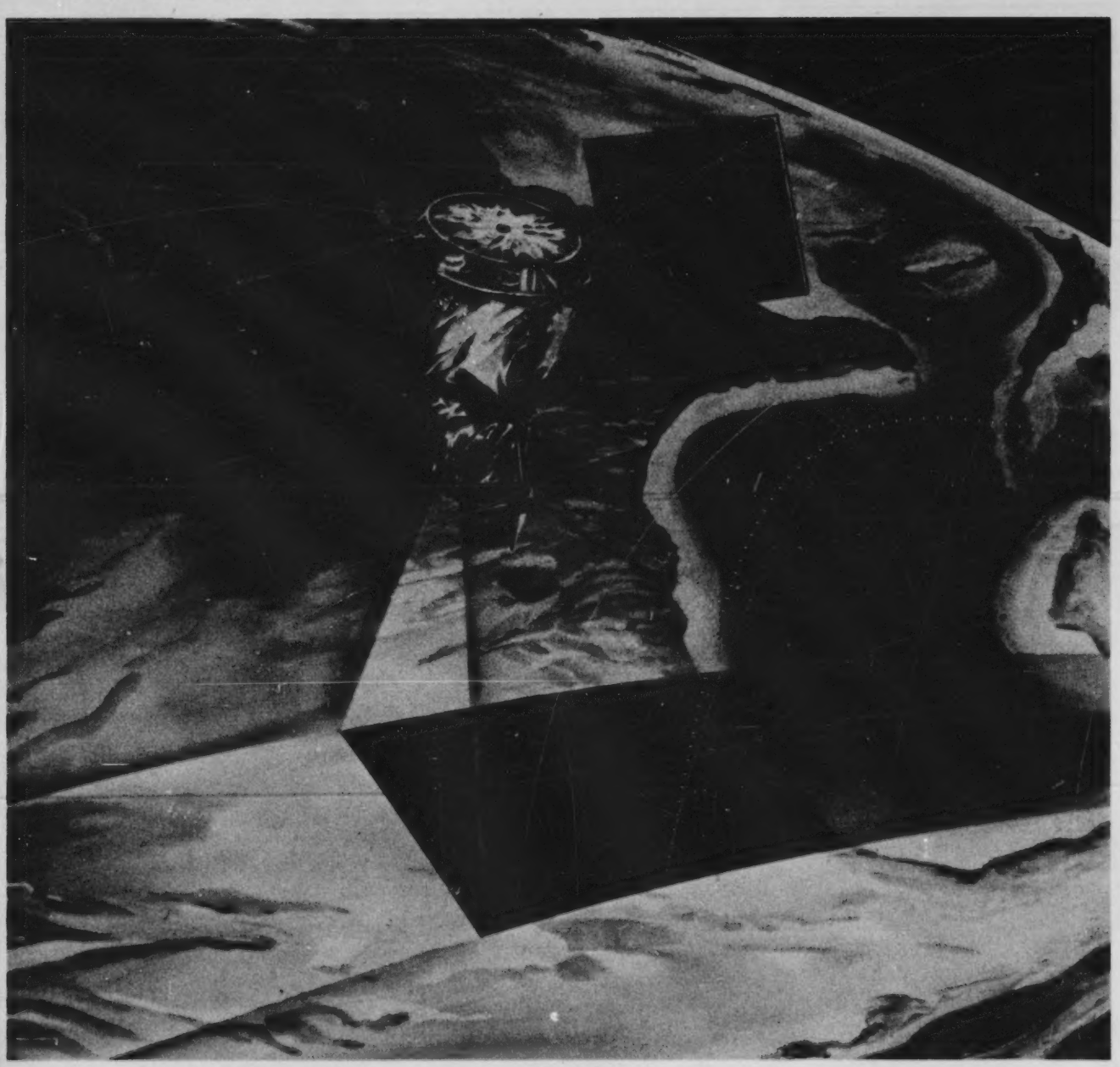




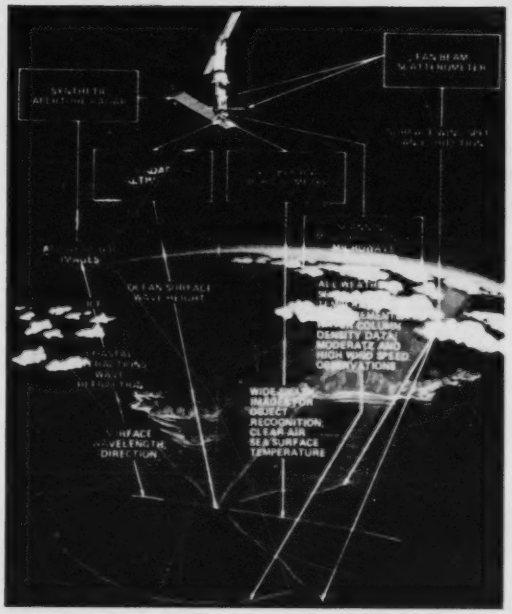
Magsat To be launched next year, Magsat is a satellite for mapping Earth's magnetic field. Its data, along with information produced by other satellites, will be used to develop a global resource map identifying promising areas for prospecting.

Landsat Versatile Landsat is one of the most important practical application systems to emerge from the space program. It offers broad economic value through its ability to produce repetitive images—electronic pictures—of changing Earth conditions. One example is Landsat's use to inventory watersheds, helping water managers to foresee flood problems, drought and water supply fluctuations. The Landsat images shown cover an area of the Sierra Nevada Mountains near Lake Tahoe on the California-Nevada border. The top right photo, taken in February 1975, shows relatively heavy snowpack; the bottom right image, taken in February 1977, shows sharply reduced snow cover. Comparison indicated severe water shortage, which in fact occurred in 1977. Landsat images like these are integrated with ground measurements of snow depth to provide accurate, broad area predictions of future water runoff and anticipated water supplies, information of great importance in water management. Landsat also has special applicability in agriculture. Its sensitive detectors can be programmed to "see" one particular kind of vegetation, so the satellite can inventory crops for predicting yield; or it can detect crop blight for early action to prevent the spread of disease. The list of other applications is lengthy and growing: identifying air and water pollutants, finding new oil and mineral resources, studying urban growth patterns, improving the accuracy of world maps, plotting changes in ecology resulting from forest fires, earthquakes and strip mining —these are just a few of many examples.

Heat Mapping A small, low-cost satellite designed to advance technology for practical applications will be launched this year to conduct a Heat Capacity Mapping Mission. The satellite, shown below, will employ a thermal mapping instrument to measure the heat of Earth surface elements such as soil and rock, providing an entirely new way of identifying soil moisture content and rock composition. Potential applications include production of thermal maps for location of mineral resources and obtaining soil moisture information to help in predicting crop yield.

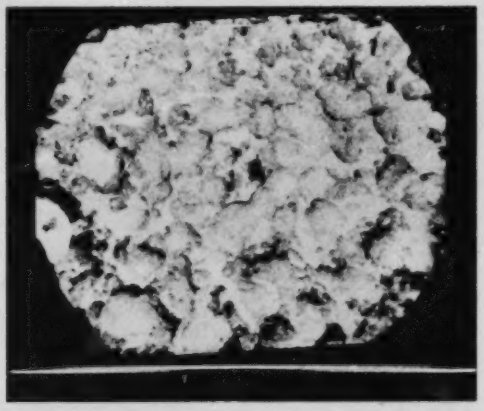


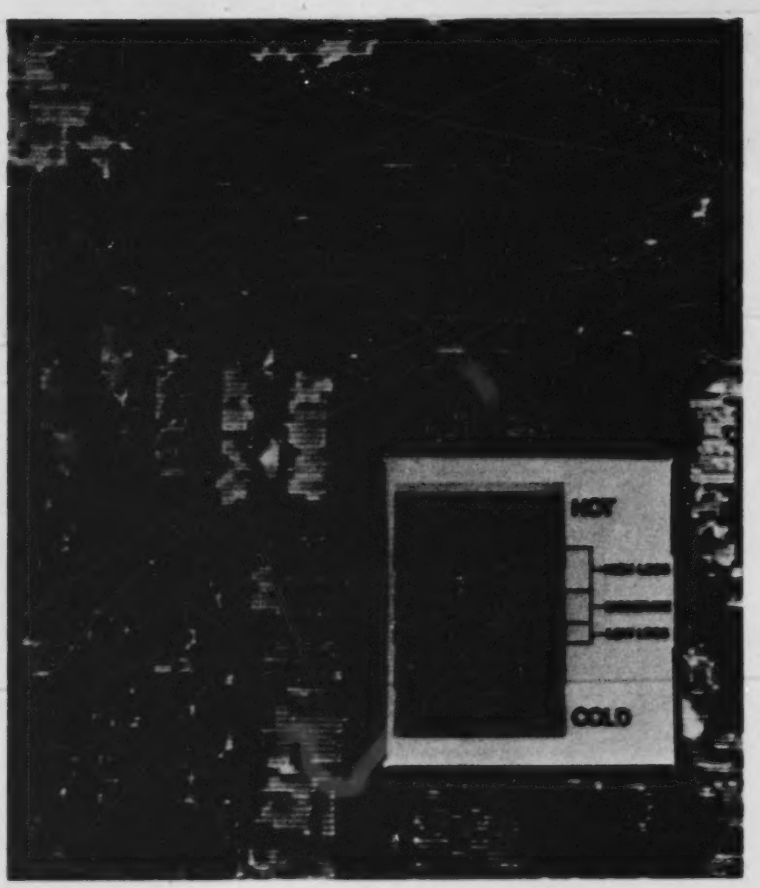
Seasat A new satellite with great potential for practical benefit is Seasat, to be launched this year. An imaging satellite similar in principle to Landsat, Seasat will report continuously on changing ocean conditions such as wave heights and direction, surface winds, current and tide patterns and ice field locations. It will be a valuable tool for maritime industries, providing information to improve ship design, ship routing, storm and iceberg avoidance and techniques for guiding fishing fleets to most productive waters. It will also warn of threatening coastal disasters and relay scientific data on the ocean environment.



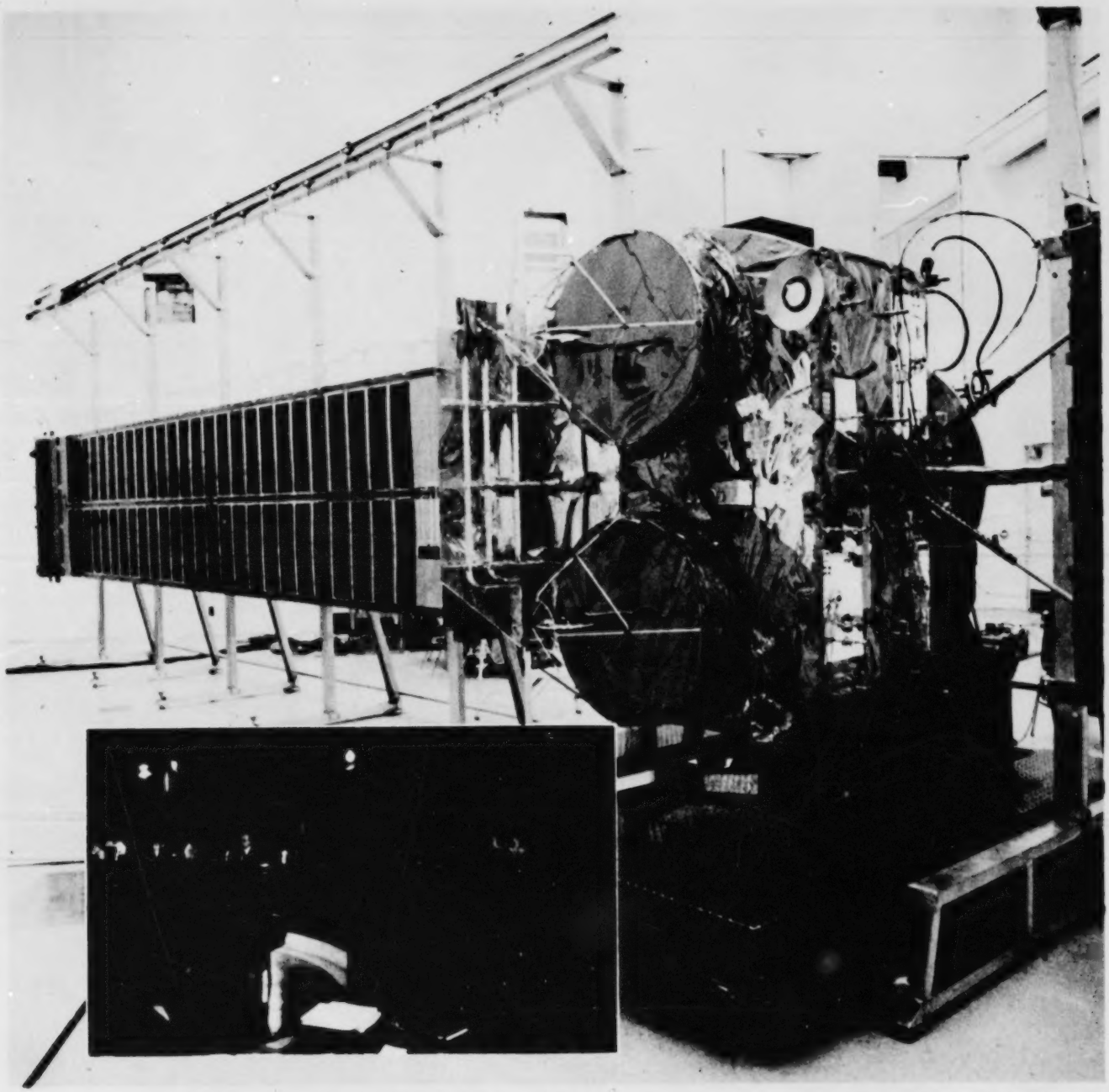
Water Quality Monitoring In cooperation with the Environmental Protection Agency and the National Oceanic & Atmospheric Administration, NASA is applying aerospace technology to important studies of water quality. Satellites provide large-area information, and aircraft equipped with remote-sensing scanners focus on specific locales. Remote sensing imagery allows monitoring the effects of such pollutants as sewage, acids, industrial wastes and oil spills; it shows polluted areas, amounts of pollutants and how they spread after dumping. The above photo, taken by NASA's Lewis Research Center at the request of the City of Cleveland and the Environmental Protection Agency, provides information on the flow and dispersion pattern of sewage flowing into Lake Erie from Cleveland's Easterly Sewage Plant.

Undersea Photo Enhancement NASA's Jet Propulsion Laboratory is exploring the application of aerospace technology to underwater survey and exploration. One system being developed uses computerized photo enhancement techniques, such as those employed in the Viking Mars mission, to improve undersea photographs and sonar images. In the illustration, the picture at right shows excellent detail of lava flows in the Atlantic Ocean; it was created by applying the enhancement process to the apparently washed out film at left.





Energy Conservation NASA is conducting demonstrations to show how aerial surveys can make a major contribution to national energy conservation. Aircraft equipped with infrared scanners fly over homes and industrial facilities, producing "thermographs" that measure radiant heat loss from rooftops and pinpoint which buildings are losing too much heat. The image shown covers a section of Cleveland, Ohio. This thermograph indicates that some degree of heat was escaping from most of the buildings scanned. The colors are the key to the amount of heat loss. Yellow shows the building is poorly insulated and very heat-wasteful. Magenta, light red and dark red warn of varying amounts of heat loss that suggest need for better insulation. Light and dark blues indicate little or no loss; many of the blue rooftops are unheated garages, which have no heat to lose. At the top of the picture is Interstate 77, which appears in red and yellow because it is radiating stored heat from the sun; other roads similarly show heat radiation colors. NASA's work is intended to encourage states and cities to use commercial infrared scanning services for spotting heat losses. Expanded use of aerial survey, together with homeowner cooperation in re-insulating, could make possible large-scale energy savings.



Communications Technology Satellite NASA is teaming with the Canadian government in an experimental satellite program designed to deliver certain types of public service communications. Now in orbit, the Communications Technology Satellite (shown above) has exceptionally high transmitting power levels, permitting reception of its signals by low cost antennas which most communities can afford. It extends satellite communications technology by obviating the need for elaborate ground reception systems and makes possible color television and two-way voice communications through small, user-operated ground terminals. An example of the satellite's utility was the assistance it provided last year to a Senate committee hearing testimony on the need for expanded weather forecasting service for farmers. Watching on several TV monitors, Senators and committee staff in a Washington hearing room were able to see, hear and query witnesses in Springfield, Illinois. Television and two-way voice signals were relayed by CTS to small, portable antennas in both cities. CTS is being used in similar demonstrations of such public service applications as education, health care and public safety.

NASA's mainline programs, such as those described in the previous section, produce a steady flow of new technology. Much of this technology is being re-used to create new products and processes that serve a wide range of public needs and conveniences, providing social and economic benefits of significant order

Technology Twice Used

A musical derivative of aerospace technology accents the breadth and economic value of spinoff

An Instrumental Innovation

Think of guitars and you think of rock and country music, or the vigorous rhythms of the gypsy flamenco, or perhaps the classical strumming of a Segovia. About the last thing you would associate with guitars is aerospace technology.

Yet there is a connection. A whole family of quality guitars is an outgrowth of helicopter rotor research conducted for the military services and NASA by an aerospace contractor. These musical spinoffs, commercially available and rapidly gaining in popularity, are the Ovation guitar line, manufactured by Ovation Instruments, Inc., Bloomfield, Connecticut.

Ovation guitars were created by Charles H. Kaman, president and founder of Ovation's parent firm, Kaman Corporation. In photo, Kaman swaps notes with entertainer Glen Campbell, one of a lengthy list of top-flight performers who use and endorse the spinoff guitars. Feedback from Campbell and others has resulted in a number of improvements to the Ovation line and on one occasion produced an entirely new model.

Ovation Instruments is a subsidiary of Kaman Corporation, a diversified company originally formed to develop and build helicopters. A helicopter's rotor system, with thousands of moving parts, is highly susceptible to vibration. For rotor efficiency, vibration must be "dampened," or reduced. Like other helicopter builders, Kaman Corporation spent years of research toward that end. The technology thus developed, together with the availability of staff experts in vibration engineering, sparked an idea in the mind of the company's president and founder, Charles H. Kaman. A guitarist of professional caliber, Kaman reasoned that vibration-dampening technology could be turned around to *enhance* vibration and thereby produce a guitar with superior sound.

Kaman researched the guitar field and found that, although the instrument had been in use since the 16th century, not much was known about the physics of the guitar with respect to its complex vibrations and their influence on sound quality. Kaman put the quest for sound excellence on a scientific basis, using special vibration analysis equipment patterned on aerospace technology. What began as a basement hobby project grew to the point where Kaman organized Ovation Instruments to manufacture and sell the guitars.

From two years of vibration analysis emerged an innovative bowl-like guitar design that Ovation researchers considered the ideal shape for full, rich and constant tones throughout the instrument's range. But it would be difficult, if not impossible, to shape traditional wood to the new design. So the Ovation team delved again into aerospace lore, investigating a number of strong, lightweight materials used in aircraft and helicopter construction. Initially, they came up with bonded fiberglass; more recently they added carbon graphite, originally developed for supersonic planes. These materials offer a number of advantages in shaping, strength, sound and producibility.

For manufacturing the guitars, Ovation made still another trip to the aerospace technology well to develop special jigs and fixtures characteristic of aerospace production techniques. This assured effective quality and cost control in the manufacturing process and reduced labor requirements; although considerable hand work is still necessary, company officials estimate that man-hours needed to produce an Ovation guitar are about one-fifth of those required to produce competitive instruments of similar quality.

Initially, Ovation produced guitars for the top of the market, mostly professional entertainers. More recently, the cost advantages of aerospace-derived production, unique in the industry, enabled the company to enter the lower cost field. Ovation is producing several hundred guitars monthly; sales, in the multimillions annually, are increasing each year.

The Ovation story is an excellent example of spinoff because it illustrates a number of points with regard to technology re-use. It shows, for instance, the universality of spinoff, its reach into virtually every avenue of everyday existence. Frequently, as is the case here, the secondary application is surprisingly remote from the original technology.

The guitar example also points up the fact that, in many instances, multiple aerospace technologies are employed in the development and manufacture of a single product. The reverse is also true: often a single technology finds multiple secondary applications, each different from the other.

Most importantly, the Ovation case underlines the economic potential of spinoff. As happens frequently, a whole new company was formed to manufacture and sell a spinoff product, with eminently successful results that contribute to the Gross National Product and to job creation.

There are many other examples of aerospace spinoff that compare in scope and economic benefit with the guitar application, technology transfers with values running into millions of dollars. Many others offer only moderate economic gain but provide significant public benefit in other ways, ranging from simple conveniences to important developments in medical technology.

For the past 16 years, under its Technology Utilization Program, NASA has been actively engaged in promoting the secondary application of aerospace technology. The results have been impressive; thousands of aerospace-originated innovations have found their way into everyday use. They are contributing to lifestyle improvement, helping solve major problems of public concern, and supporting the national economy by increasing industrial efficiency, stimulating productivity and creating new jobs. In the aggregate, they represent a substantial return on the aerospace investment.

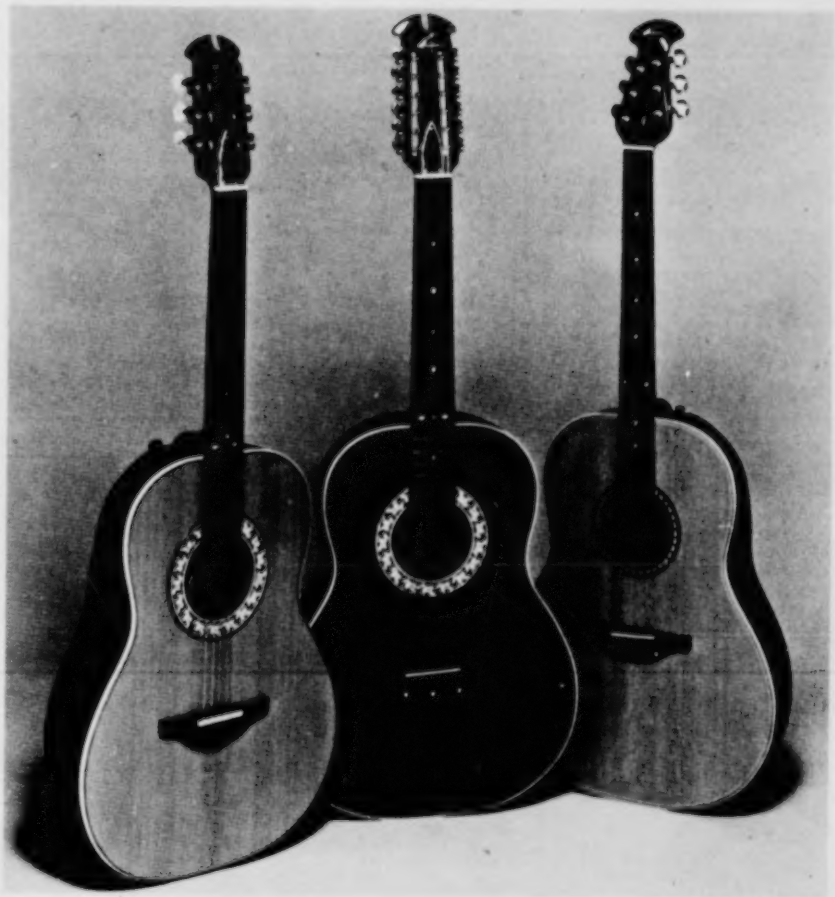


Photo shows three of more than a score of guitar models that make up the Ovation line, which traces its origin to helicopter rotor research. Ovation Instruments, Inc. also uses aerospace-developed materials and aerospace production techniques in the manufacture of the instruments. Ovation Instruments is a "spinoff company," one formed to merchandise an aerospace technology transfer. The firm turns out several hundred guitars monthly and sales are in the multimillions annually, underlining the economic value to the nation of major spinoffs.

A 10-acre stadium enclosure highlights examples of aerospace spinoff in the field of construction

A Roof For The Lions' House

Fans of the National Football League's Detroit Lions don't worry about game-day weather. Their magnificent new Pontiac Stadium has a domed, air-supported, fabric roof that admits light but protects the playing field and patrons from the elements. The 80,000-seat "Silverdome" is the world's largest fabric-covered structure—and aerospace technology played an important part in its construction.

The key to economical construction of the Silverdome—and many other types of buildings—is a spinoff of fiber glass Beta* yarn coated with Teflon** TFE fluorocarbon resin. The big advance it offers is permanency. Fabric structures—tents, for example—have been around since the earliest years of human civilization. But their coverings—hides, canvas and more recently plastics—were considered temporary; though tough, these fabrics were subject to weather deterioration. Teflon TFE-coated Beta Fiberglas is virtually impervious to the effects of weather and sunlight and it won't stretch, shrink, mildew or rot, thus has exceptional longevity; it is also very strong, lightweight, flame resistant and requires no periodic cleaning, because dirt will not stick to the surface of Teflon TFE. And to top all that, it costs only 30 to 40 percent as much as conventional roofing. Coated fibrous glass has sparked new interest in fabric structures; it is finding wide application as permanent roofing for a growing number of buildings ranging from a vocational school in wintry Alaska to a recreational facility amid the scorching sands of Saudi Arabia.

The material's origin dates to 1967, when NASA was looking for a new fabric for Apollo astronauts' space suits. It had to be durable and noncombustible, yet thin, light and flexible. Owens-Corning Fiberglas Corporation, Toledo, Ohio, had been experimenting with an ultra-fine glass fiber yarn called Beta yarn, which seemed to fill the bill. Under NASA contract, Owens-Corning wove the yarn into a fabric, coated it with Teflon TFE, manufactured by Du Pont Company, Wilmington, Delaware, and tailored it for astronaut wear. Later, to adapt the material to construction use, Owens-Corning thickened the yarn, Chemical Fabrics, Inc., Bennington, Vermont wove it into a stronger and more porous fabric, and applied a heavier coating of Teflon TFE. The three companies have teamed with the pioneer firm in air-supported structures— Birdair Structures, Inc., Buffalo, New York—to construct a variety of fabric-enclosed buildings, among them the Silverdome.

The Silverdome story illustrates why fiber glass Beta yarn coated with Teflon TFE has a bright future in the construction industry. The city of Pontiac, some 25 miles north of downtown Detroit, developed a plan to build an all-purpose stadium. The prime purpose was to provide a home for the Lions, but the Pontiac Stadium Authority wanted a year-round facility that could generate more income by housing such events as conventions, concerts, rodeos, circuses, and trade shows. Michigan's winter weather demanded an enclosed structure, but financing was limited and the cost of a steel-roofed stadium was prohibitive; New Orleans' Superdome, for example, had cost $168 million. When architects and consulting engineers advanced the fabric dome idea and estimated a very low $10 million roofing cost, Pontiac officials speedily adopted the plan. They budgeted $56 million for total construction costs and, incredibly, completed the stadium slightly below that figure.

* Registered trademark, Owens-Corning Fiberglas Corporation
** Registered trademark, Du Pont Company

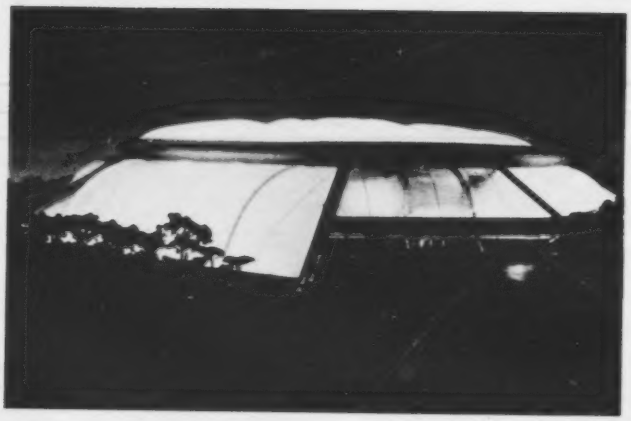
In construction, the 10-acre fabric envelope was stretched over a reinforcing network of steel cables anchored to a concrete ring running around the top of the stadium. To provide primary support, the envelope's compartments were inflated by 29 air-blowing fans; after initial inflation, only two or three fans are required to maintain pressure and the rest are used for ventilation. The completed fabric dome weighs only 200 tons, where a comparably-sized conventional roof would weigh about 6,000 tons. This is an economic bonus in addition to the basically low cost of fabric enclosure; the lighter weight means reduced load bearing requirements for the foundation, hence less steel and concrete.

The team of Owens-Corning, Du Pont, Chemical Fabrics and Birdair have collaborated on a number of fabric structures. Some are supported by air pressure, others by cables alone. Most of the structures are in the recreational category—stadia, athletic field houses, swimming pools, tennis courts—but the technique has also been used in schools, theaters, exhibit halls and industrial facilities. With conventional construction costs still on the upswing, you're likely to see a great many more permanent facilities enclosed by the aerospace spinoff fabric.

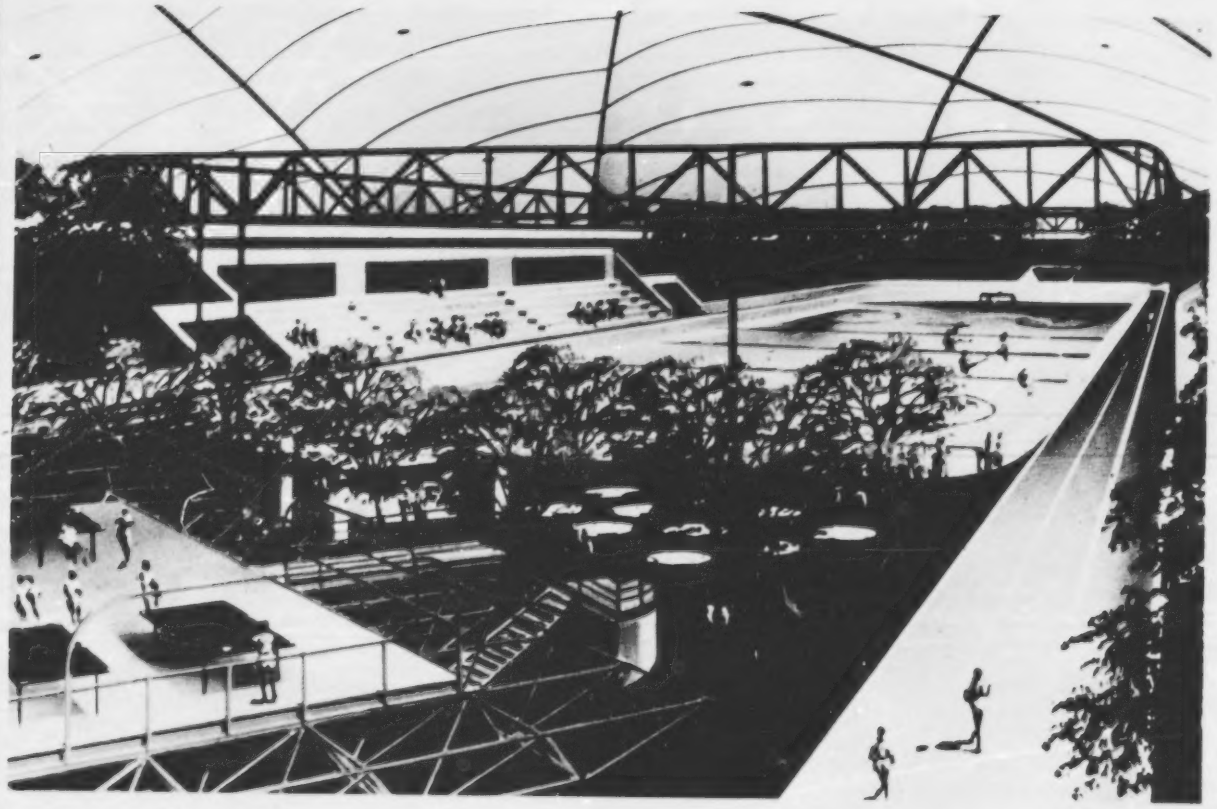
The Silverdome, home of the Detroit Lions at Pontiac, Michigan, has an air-supported, domed fabric roof for year-round utility. The coated fiber glass fabric is a strong, flame-resistant material originally developed for astronauts' space suits.

Du Pont Company

The University of Santa Clara, California has a two-unit air-supported, fabric-covered facility. The larger structure is a 6,000-seat fieldhouse for athletic competitions and special events, the smaller houses a swimming pool.

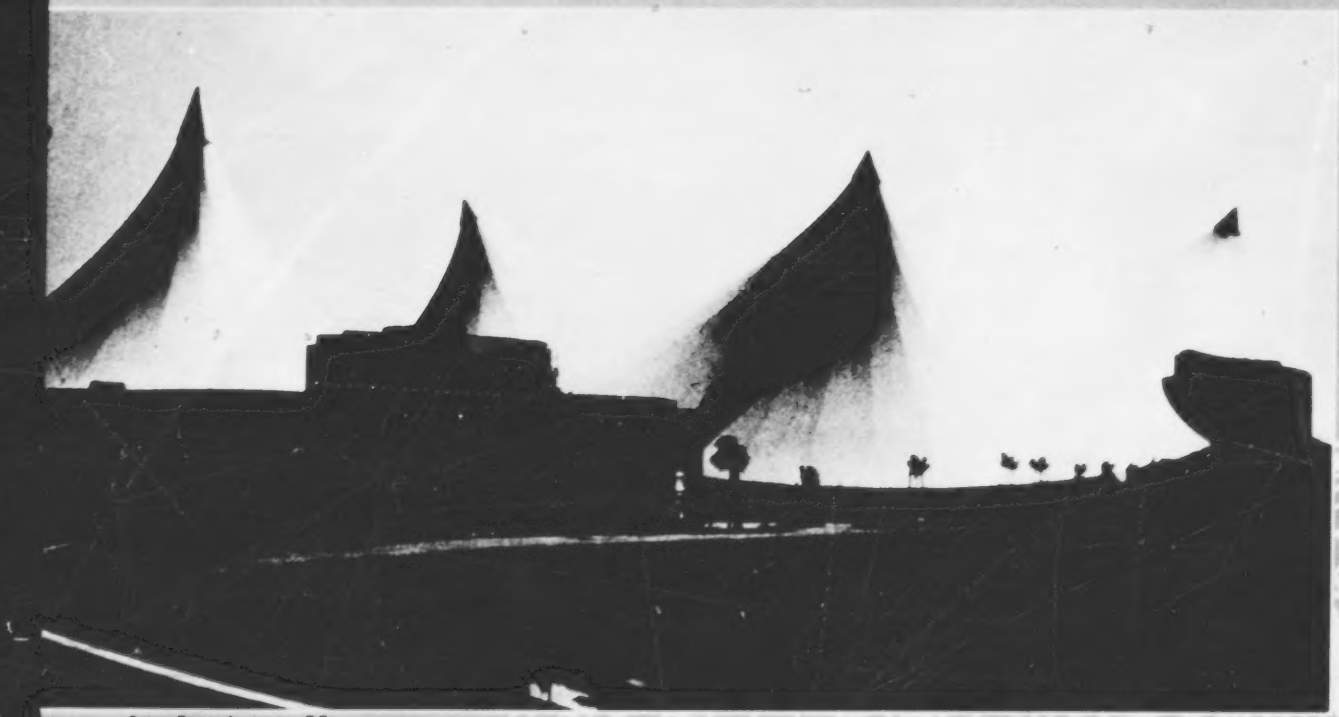


Air-supported structures covered with coated fiber glass fabric—such as this activities center at the University of Florida, Gainesville—offer substantial savings in construction costs. Caudill Rowlett Scott are the design consultants. Moore May and Harrington of Gainesville, Florida are architects for this project.



Tension Structure The fabric structure pictured is the Campus Center of La Verne College, La Verne, California. Unlike the facilities shown on the preceding pages, it is not air-supported. It is a "tension structure," its multi-coned fabric membrane supported by a network of cables attached to steel columns which function like circus tent poles. The spider-web in the accompanying photo is a computer graph of the tension pattern. The designers, Geiger-Berger Associates PC, of New York City, conducted lengthy computer analysis to determine the best placement of columns and cables. The firm also served as structural engineering consultant on the Pontiac Silverdome and a number of other large fabric structures.

Built by Birdair Structures, Inc., Buffalo, New York, the La Verne Campus Center was the first permanent facility in the United States enclosed by the space-spinoff fabric made of Owens-Corning Beta fiber glass coated with Du Pont Teflon TFE. The flexible design permits rearrangement of the interior to accommodate athletic events, student activities, theatrical productions and other recreational programs. Use of fabric covering reduced building cost 30 percent below conventional construction.



Geiger Berger Associates, P.C.

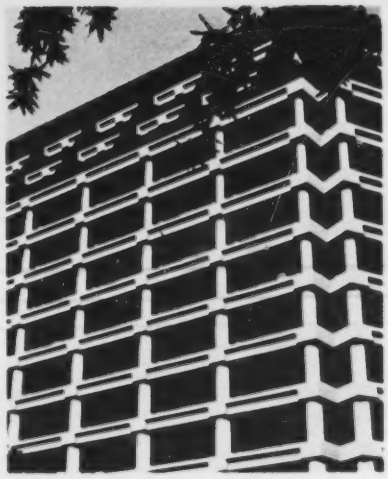
Building Specifications The building in the top photo is the new home of the National Permanent Savings Bank in Washington, D.C., designed by Hartman-Cox Architects. Its construction was based on a money-saving method of preparing building specifications which derived from NASA technology developed to obtain quality construction while holding down cost of launch facilities, test centers and other structures.

Written technical specifications spell out materials and components to be used on construction projects and identify the quality tests each item must pass. Specifications can have major impact on construction costs. Poorly formulated specifications can lead to unacceptable construction which must be replaced, unnecessarily high materials costs, safety hazards, disputes and often additional costs due to delays and litigation.

NASA's Langley Research Center developed a novel approach to providing accurate, uniform, cost-effective specifications which can be readily updated to incorporate new building technologies. Called SPECSINTACT, it is a computerized system accessible to all NASA centers involved in construction programs. The system contains a comprehensive catalog of master specifications applicable to many types of construction. It enables designers of any structure to call out relevant sections from computer storage and modify them to fit the needs of the project at hand. Architects and engineers can save time by concentrating their efforts on needed modifications rather than developing all specifications from scratch.

Successful use of SPECSINTACT has led to a number of spinoff systems. One of the first was MASTERSPEC, developed from NASA's experience by Production Systems for Architects and Engineers, Inc., an organization established by the American Institute of Architects. MASTERSPEC (shown at right), used in construction of the bank building pictured, follows the same basic format as SPECSINTACT and can be used in either automated or manual modes. The striking appearance of the bank building shows that, while MASTERSPEC saves time and money, its use involves no sacrifice in architectural design freedom.

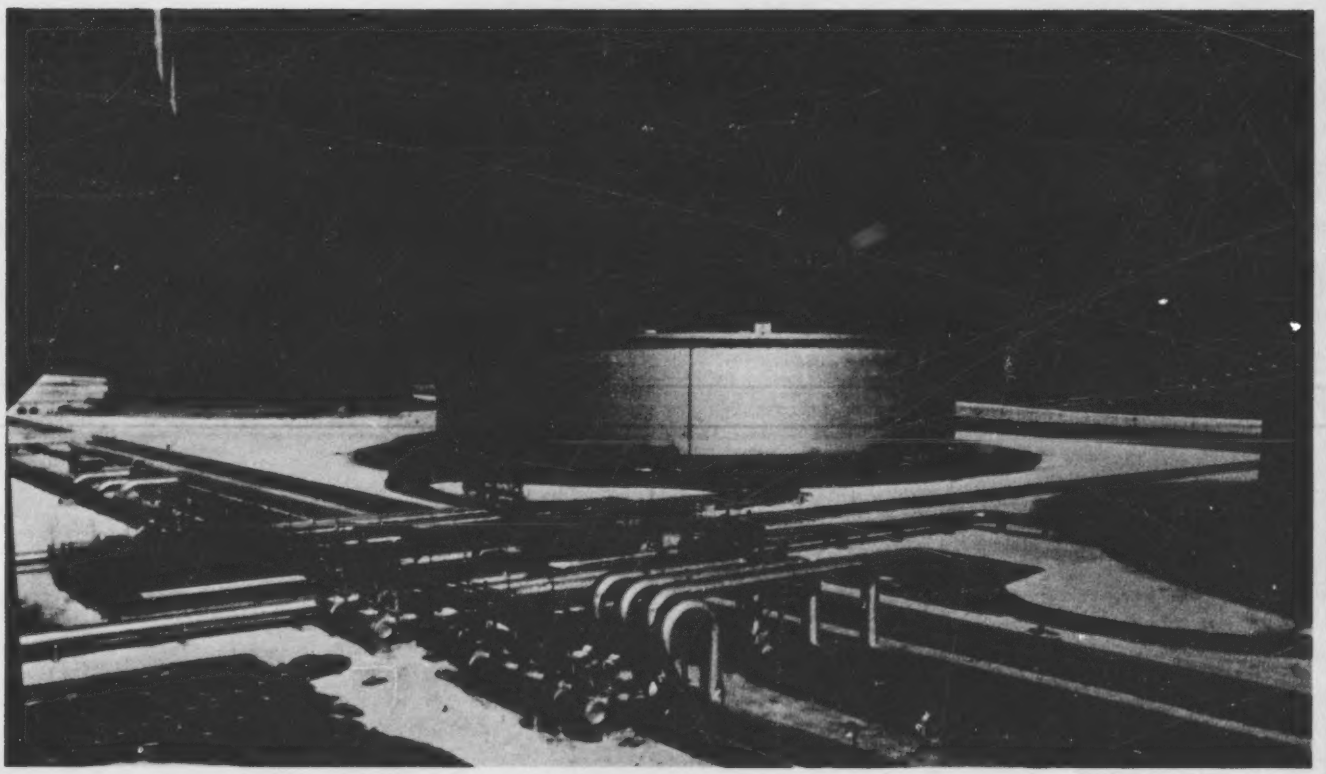
The Naval Engineering Facilities Command employs an automated specifications system based on SPECSINTACT. The Public Buildings Service of the General Services Administration uses SPECSINTACT as a starting point in a plan to make its guideline specifications available to architects and engineers on a nationwide computer network. Public Technology, Inc., a NASA Technology Application Team, is working with Production Systems for Architects and Engineers., Inc., to promote widespread use of the system by state and local governments for cost benefits to taxpayers.



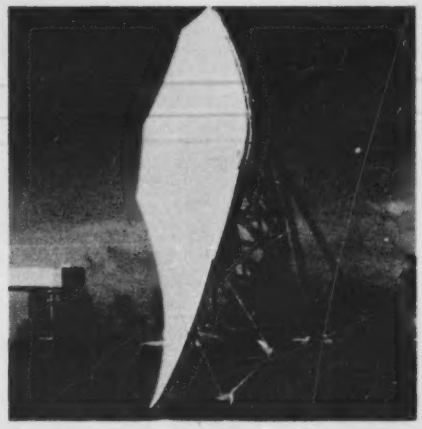
Computer Programs For Construction NASA and its contractors have long used computer design techniques in the construction of airplanes and spacecraft. Computers enable engineers to make mathematical models of an aerospace vehicle and simulate its flight. In this manner, they can study the performance and structural behavior of many different designs before making a decision as to final configuration.

The technology is widely applicable to non-aerospace use. NASA has developed a number of general purpose computer programs that are available to the civil sector. Best known and most widely used is NASTRAN, an acronym for NASA Structural Analysis Program. Developed by Goddard Space Flight Center and now being maintained by Langley Research Center, NASTRAN electronically analyzes a computerized design and predicts how it will react to many different conditions of stress and strain. It can, for example, predict the effects of high temperature on metal components. By minimizing error in the design process, NASTRAN makes possible better, safer, lighter structures and offers substantial savings in reduced development time and materials requirements.

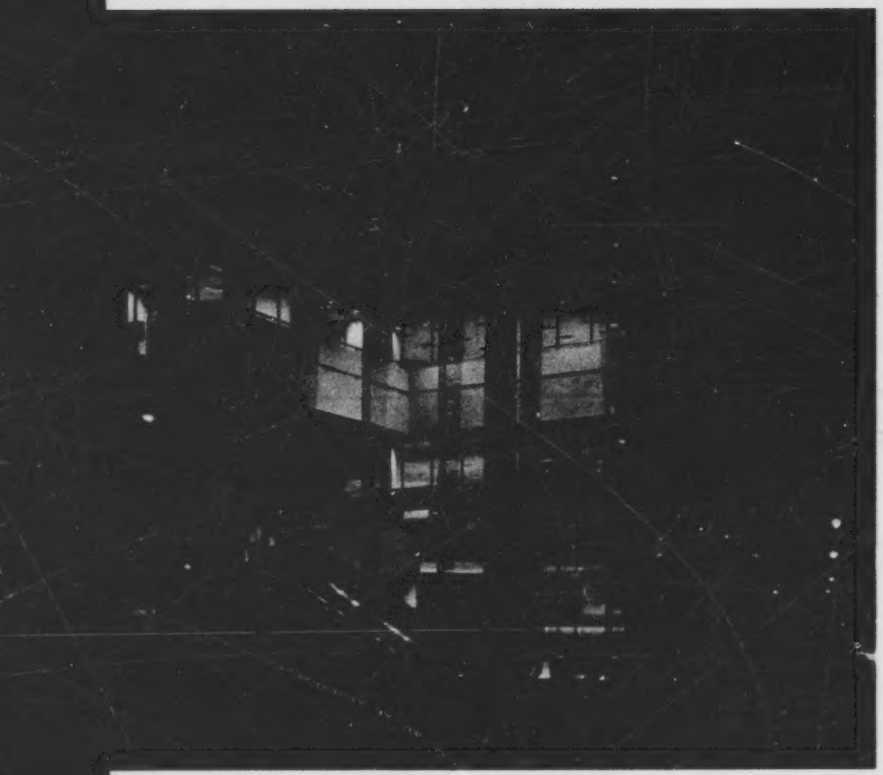
NASTRAN and other computer programs are available to private industry through NASA's Computer Software Management and Information Center (COSMIC) at the University of Georgia. COSMIC maintains a library of NASA computer programs and those of other technology-generating federal agencies. The programs are offered for sale at a fraction of their original cost and in most instances the return is many times the investment; sometimes savings run to several million dollars. These computer programs represent one of the broadest areas of economic benefit from the secondary use of aerospace technology. They have found special utility in the field of construction; some typical applications are shown on these two pages.



Piping Flexibility A NASA computer program aids Hudson Engineering Corporation, Houston, Texas, in the design and construction of huge petrochemical processing plants like the one shown, which is located at Ju'aymah, Saudi Arabia. The pipes handling the flow of chemicals are subject to a variety of stresses, such as weight and variations in pressure and temperature. Hudson Engineering uses a COSMIC piping flexibility analysis computer program to analyze stresses and insure the necessary strength and flexibility of the pipes. This program helps the company realize substantial savings in reduced engineering time.



Comsat Antenna The antenna shown is the new, multiple-beam, Unattended Earth Terminal, located at COMSAT Laboratories in Clarksburg, Maryland. Seemingly simple, it is actually a complex structure capable of maintaining contact with several satellites simultaneously (conventional Earth station antennas communicate with only one satellite at a time). In developing the antenna, COMSAT Laboratories used NASTRAN, NASA's structural analysis computer program, together with BANDIT, a companion program. The computer programs were used to model several structural configurations and determine the most suitable. The speed and accuracy of the computerized design analysis afforded appreciable savings in time and money.



Picture Wall Photo shows a subway station in Toronto, Ontario, which is entirely glass-enclosed. The all-glass structure was made possible by a unique glazing concept developed by PPG Industries, Pittsburgh, Pennsylvania, one of the largest U.S. manufacturers of flat glass. In the TVS glazing system, transparent glass "fins" replace conventional vertical support members used to provide support for wind load resistance. For stiffening, silicone sealant bonds the fins to adjacent glass panels. At its glass research center near Pittsburgh, PPG Industries uses the NASTRAN computer program to analyze the stability of enclosures made entirely of glass. The company also uses NASTRAN to simulate stresses on large containers of molten glass and to analyze stress effects of solar heating on flat glass.

Solar Meter The instrument pictured is an inexpensive solar meter which is finding wide acceptance among architects, engineers and others engaged in construction of solar energy facilities. It detects the amount of solar energy available at a building site, information necessary to design the most efficient type of solar system for a particular location.

Incorporating technology developed by NASA's Lewis Research Center, the device is based upon the solar cell, which provides power for spacecraft by converting the sun's energy to electricity. The meter is produced by Dodge Products, Inc., Houston, Texas, a company formed to bring the technology to the commercial marketplace.

In the Dodge meter, the amount of the sun's radiation reaching the ground is detected by a single solar cell. The information is displayed by a needle pointer which gives a reading in heat or electrical units. A number of readings are taken at different times of day and summed to get total daily radiation. For information as to the energy available over a lengthy period of time, Dodge Products offers a companion device, called an integrator, which makes the measurements and computations automatically.

In addition to its utility as a solar system design aid, the meter has several other applications. For example, a company that produces glare reducing film uses the instrument to show customers the difference in solar penetration between ordinary glass and the company's specially film-coated glass. A similar application is measurement of the transmitting qualities of transparent materials. The meter is used to check the performance of concentrators, lenses and mirrors used in solar energy systems. Federal and state solar energy planners, research laboratories and educators teaching subjects that deal with solar radiation also use it.

Bolt Stress Monitor In photo, an engineer is using a new Ultrasonic Bolt Stress Monitor developed by NASA's Langley Research Center to determine whether a bolt is properly tightened. A highly accurate device, the monitor is an important tool in construction of such structures as pressure vessels, bridges and power plants, wherein precise measurement of the stress on a tightened bolt is critical. Overtightened or undertightened bolts can fail and cause serious industrial accidents or costly equipment break-downs.

There are a number of methods for measuring bolt stress. Most widely used and least costly is the torque wrench, which is inherently inaccurate; it does not take into account the friction between nut and bolt, which has an influence on stress. At the other end of the spectrum, there are accurate stress-measuring systems, but they are expensive and not portable.

The battery-powered Langley monitor fills a need; it is inexpensive, lightweight, portable and extremely accurate because it is not subject to friction error. Sound waves are transmitted to the bolt and a return signal is received. As the bolt is tightened, it undergoes changes in resonance due to stress, in the manner that a violin string changes tone when it is tightened. The monitor measures the changes in resonance and provides a reading of real stress on the bolt. The device, patented by NASA, has aroused wide interest and a number of firms have applied for licenses to produce it for the commercial market.

Tech House The members of the Swain family—Dr. Charles "Bill" Swain, wife Elaine, daughter Carol, 17, son "Chuck", 12, and dog Susie—have an interesting assignment. They are active participants in an important NASA research program involving the application of space-age technology to home construction.

Transplanted Floridians, the Swains now reside in NASA's Tech House, located at Langley Research Center, Hampton, Virginia. Their job is to use and help evaluate the variety of advanced technology systems in Tech House. A contemporary three-bedroom home, Tech House incorporates NASA technology, the latest commercial building techniques and other innovations, all designed to reduce energy and water consumption and to provide new levels of comfort, convenience, security and fire safety.

Tech House equipment performed well in initial tests, but a house is not a home until it has people. That's where the Swains come in. NASA wants to see how the various systems work under actual living conditions, to confirm the effectiveness of the innovations or to determine necessary modifications for improvement. The Swains are occupying the house for a year, during which NASA engineers are computer-monitoring the equipment and assembling a record of day-to-day performance.

Tech House is a laboratory rather than a mass production prototype, but its many benefits may influence home design and construction. In a period of sharply rising utility costs, widespread adoption of Tech House features could provide large-scale savings to homeowners and potentially enormous national benefit in resources conservation.

Most innovations are aerospace spinoffs. Some of the equipment is now commercially available; other systems are expected to be in production within a few years. Around 1980, a Tech House-type of home could be built for $45-50,000 (1976 dollars). It is estimated that the homeowner would save well over $20,000 (again 1976 dollars) in utility costs over the average mortgage span of 20 years.

Tech House is designed to use only one-third the energy of a comparably-sized home. Among the energy-saving features are solar collectors for heating the home and providing domestic hot water; a roof radiator system for summer cooling; super-efficient insulation, including

heat-blocking material up to six inches thick, double-paned windows and thermal shutters; exterior design features that admit or reduce sun heat, depending on the season; a high-efficiency fireplace that cuts chimney loss of heat; and a computer-directed comfort control system that heats or cools only the rooms in use at a given time.

Tech House uses less than half the water of a comparable home. It has a partial recycling system that collects waste water from the shower, bathtub and washing machine and re-uses it for toilet flushing. Special nozzle inserts in shower heads and a smaller than usual commode also trim water usage.

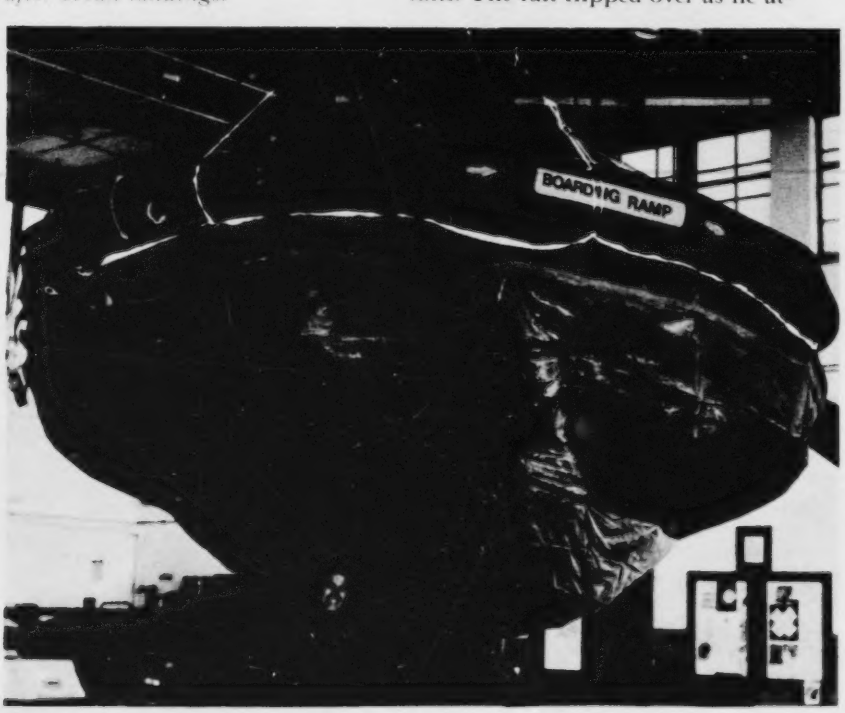
Security and safety measures include non-flammable insulation; fire-retardant materials in curtains, furniture and carpets; a sophisticated fire detection system; a tornado warning device; and several innovations, including unique locks and break-in detectors.

The Tech House project is sponsored by NASA's Technology Utilization Division. The study and design for the Tech House was supported by a great many organizations, including NASA field centers, the Department of Housing and Urban Development, the National Bureau of Standards, the Consumer Products Safety Commission, the National Association of Home Builders Research Foundation, Old Dominion University, Hampton Institute, and Technology and Economics Inc. The basic Tech House design was contributed by the architectural firms of Forrest W. Coile & Associates and Charles W. Moore & Associates.

Among a number of safety-improving technology transfers is a new inflatable liferaft that represents a major advance in equipment for sea emergencies

Spinoff For Survival

Operating off Kodiak, Alaska, the 82-foot fishing boat *Credence* recently overturned in high seas. Fortunately, its crew of six had time to board a uniquely-stabilized, inflatable liferaft known as the Givens Buoy Raft. One of the crewmen had particular cause to appreciate the value of the new Givens raft. On a previous occasion, he had been forced to abandon another fishing vessel which carried conventional flat-bottom inflatable rafts. The raft flipped over as he attempted to board it and he was saved only by the timely arrival of a rescue helicopter.



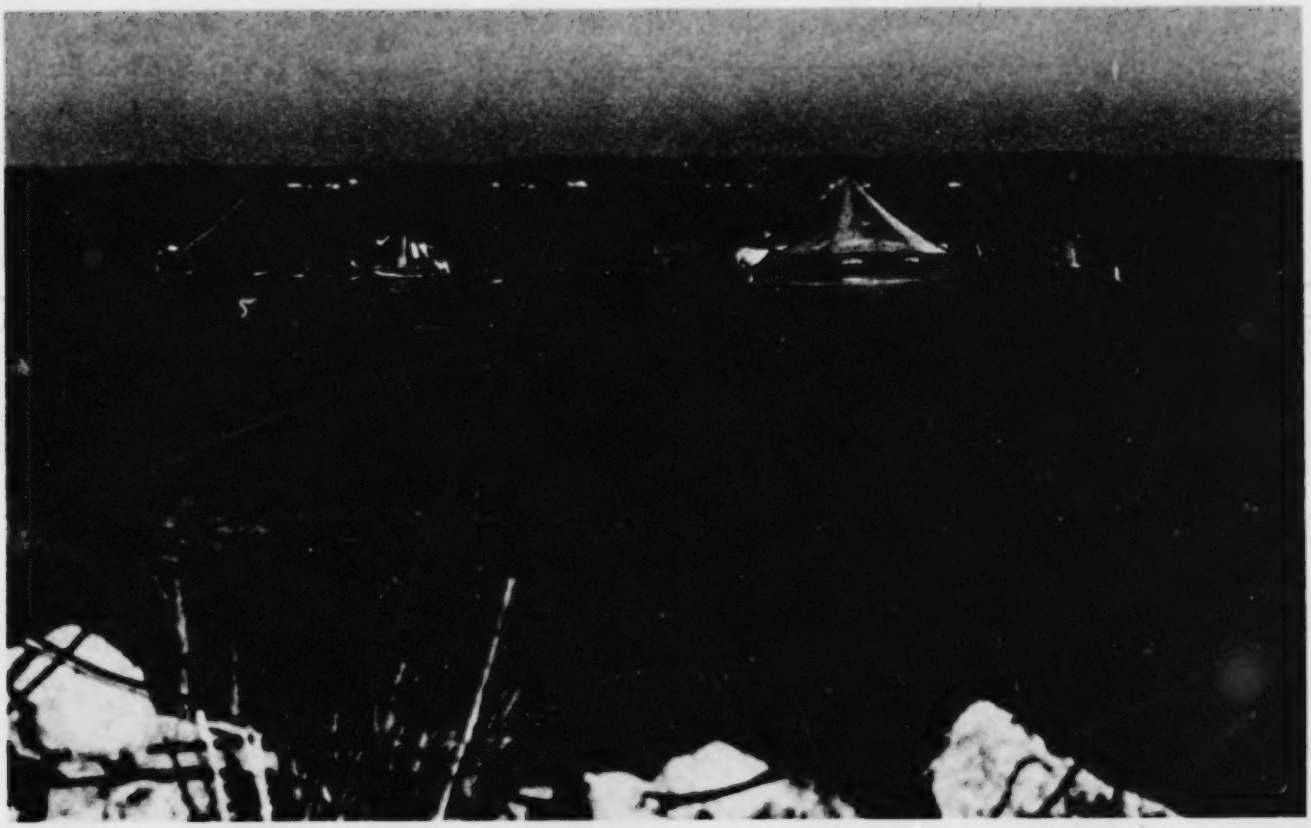
The Givens Buoy Raft, shown in a hangar prior to Elizabeth City tests, has an unusual hemispheric underside, designed to prevent capsizing in rough water. The design is similar to that of a NASA raft developed for stable performance in astronaut recovery after ocean landings.

The Givens Buoy Raft cannot be overturned, its manufacturer claims and others concur. An independent test group conducted a series of demonstrations and found that every type of raft except the Givens could be capsized either by one man boarding or several shifting weight within the raft. Termed by the group "a remarkable stability achievement," the Givens Buoy raft offers the first major advance in inflatable survival equipment in many years. It is a spinoff product resulting in part from NASA technology and in part from years of research by Jim Givens, president of Res-Q-Raft, Inc., of Lake Worth, Florida and Seattle, Washington.

NASA used inflatable rafts to transfer astronauts returning from space between their ocean-landed spacecraft and a recovery ship. NASA found a problem in the use of conventional flat-bottom inflatables; they tended to overturn when exposed to the downdraft from helicopters of the recovery fleet. So Johnson Space Center developed a new and highly-effective method of raft stabilization for which NASA secured a patent. Working separately, Jim Givens came up with a very similar system. He subsequently patented his own invention and secured an exclusive patent license to use the NASA technology.

Many seagoing vessels, particularly fishing boats, use inflatable liferafts as primary survival equipment. U.S. Coast Guard approval of American-built rafts requires certain stability measures, such as stabilizing water bags or "pockets." But there is a question as to whether these devices are adequate, considering that most vessel abandonments occur under severe weather conditions. Foremost among the hazards is the possibility that inflatables may capsize in rough water either before boarding, during boarding or from weight shifts after evacuees have boarded. The rafts may also flip under the pressure of rotor downwash when helicopters are employed in the rescue operation. Additionally, an inflatable dropped into heavy seas may part its tie-line and float out of reach before crewmen can board it.

The Givens Buoy Raft, the basic model of which has a capacity of four to six persons, was designed in re-



At Elizabeth City, North Carolina, several inflatable liferafts of various designs await their turns for stability testing. The tests were conducted last year as part of a new Coast Guard study of inflatable survival equipment.

sponse to these hazards. The design elimates the conventional limited-ballast water bags. In their stead is one large hemisphere-shaped underwater ballast chamber which provides exceptional stability. The chamber has a "flapper valve" that admits 4,800 pounds of water ballast. The ballast chamber moves *with* the wave action and thus, says inventor Givens, the raft cannot overturn even if all the occupants shift to one side. The ballast chamber also keeps the raft from blowing away in high winds. An additional feature is the raft's ability to right itself if it is accidentally inflated upside-down.

Some manufacturers of conventional rafts say that no improvements are needed on Coast Guard-approved inflatables. The Coast Guard, however, is not sure about that; officials have been following closely the Givens development and they are considering the possible necessity for upgrading raft stabilization standards.

Last October, at Elizabeth City, North Carolina, the Coast Guard conducted a series of stability tests on several rafts —including Givens'—of varying size and design. That was part of a comprehensive test and study program, still under way, of the performance and effectiveness of inflatable survival equipment. It could result in a new set of standards.

Meanwhile, the Givens Buoy Raft is finding wide acceptance among operators of fishing boats and other vessels. It has also won a nod of approval from the fishing industry publication National Fisherman. Reporting on a survey of expert opinion as to the relative merits of different inflatables, the publication stated: "There is a definite consensus that the Givens raft is the most suitable for the greatest variety of likely conditions."

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In this underwater view, the diver is examining the "flapper valve" of the Givens Buoy Raft. The valve admits water to the large hemispheric ballast chamber, key to the raft's exceptional stability.

Radiation Hazard Detector NASA technology has made commercially available a new, inexpensive, conveniently-carried device for protection of people exposed to potentially dangerous levels of microwave radiation.

Microwaves are radio emissions of extremely high frequency. They can be hazardous but the degree of hazard is not yet well understood. Generally, it is believed that low intensity radiation of short duration is not harmful but that exposure to high levels can induce deep internal burns, affecting the circulatory and nervous systems, and particularly the eyes.

The Department of Labor's Occupational Safety and Health Administration (OSHA) has established an allowable safe threshold of exposure. However, people working near high intensity sources of microwave energy—for example, radar antennas and television transmitters—may be unknowingly exposed to radiation levels beyond the safe limit. This poses not only a personal safety problem but also a problem for employers in terms of productivity loss, workman's compensation claims and possible liability litigation.

Earlier-developed monitoring devices which warn personnel of dangerous radiation levels have their shortcomings. They can be cumbersome and awkward to use while working. They also require continual visual monitoring to determine if a person is in a dangerous area of radiation, and they are relatively expensive, another deterrent to their widespread adoption.

In response to the need for a cheaper and more effective warning system, Jet Propulsion Laboratory developed, under NASA auspices, a new, battery-powered Microwave Radiation Hazard Detector. To bring the product to the commercial market, California Institute Research Foundation, the patent holder, granted an exclusive license to Cicoil Corporation, Chatsworth, California, an electronic components manufacturer.

Cicoil calls the unit the Micro-Gard* Model 100. Weighing only four ounces and about the size of a long cigarette pack, it can be carried in a shirt pocket or conveniently clipped to a worker's belt. The unit sounds an audible alarm when microwave radiation reaches a preset level—the OSHA safe limit or another threshold level decided by the user organization. Simple in design, it is priced well below earlier detectors. Production started last spring and already Cicoil's customers include numerous federal agencies and over 200 industrial users, including many of the nation's largest industrial firms.

*Registered trademark, Cicoil Corporation

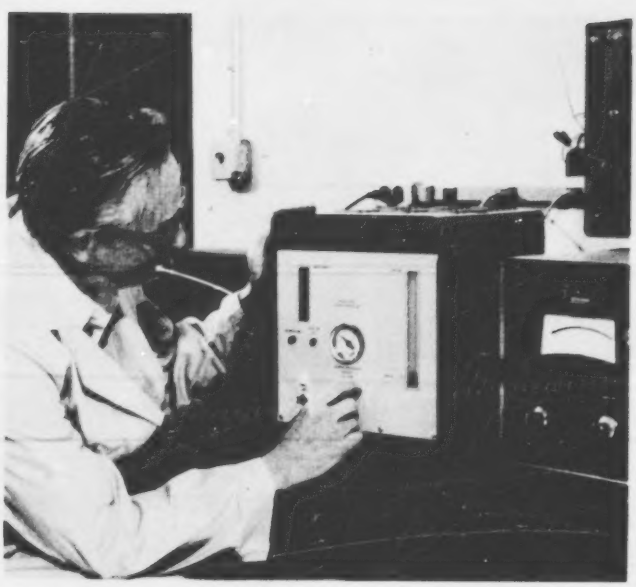
Carbon Monoxide Sensor In top photo a General Electric Company engineer is taking a reading of the carbon monoxide level in an industrial facility. The instrument he is using is GE's new Carbon Monoxide Dosimeter, an adaptation of spacecraft fuel cell technology.

The fuel cell is a system which employs an electrochemical process to convert gases—such as hydrogen and oxygen—directly into electricity. Under NASA sponsorship, GE's Aircraft Equipment Division developed fuel cells to supply electrical power for the Gemini and Biosatellite spacecraft of the sixties and is currently working on advanced fuel cell development. This long-term effort has resulted in a series of spinoff applications using the same general technology for a variety of purposes, among them the recently marketed Dosimeter.

The Dosimeter is designed to help users meet safety requirements for industrial atmospheres, as specified by the Occupational Safety and Health Administration and other regulatory agencies. The compact, pocket-sized sensor measures personnel exposure to carbon monoxide and provides both a visual and an audible alarm if the concentration of the gas exceeds preset levels. The Dosimeter offers substantial improvement in measuring accuracy over earlier warning indicators.

The larger photo shows the sensor being used in conjunction with a related GE system, the Dosimeter Support Console. The latter device is a digital calculator and display unit which gives a readout of the carbon monoxide level at a given instant, along with a measurement of the accumulated dosage over a period of time.

The Dosimeter is in production and deliveries started late last year. It is the first member of a planned family of GE portable and stationary electrochemical sensors designed to monitor various toxic gases and vapors.



Hydrogen Generator Another spinoff from spacecraft fuel cell technology is the portable hydrogen generator shown. Developed by General Electric Company, it is an aid to safer operation of systems that use hydrogen—for example, gas chromatographs, used in laboratory analysis of gases, or flame ionization detectors used as pollution monitors. The generator eliminates the need for high-pressure hydrogen storage bottles, which can be a safety hazard, in laboratories, hospitals and industrial plants. The unit supplies high-purity hydrogen by means of an electrochemical process which separates the hydrogen and oxygen in distilled water. The oxygen is vented away and the hydrogen gas is stored within the unit for use as needed. GE's Aircraft Equipment Division is producing about 1,000 of the generators annually.

Firefighting Module NASA and the U.S. Coast Guard are working jointly to develop a helicopter transportable firefighting module that can shave precious minutes in combating shipboard or harbor fires. The program was undertaken in 1975, after a series of disastrous fires on oil tankers indicated a need for a lightweight, self-contained system that could be moved quickly to the scene of a fire. A prototype module was delivered to the Coast Guard last year and service testing is under way.

The compact module weighs little more than a ton but it contains everything needed to fight a fire. The key component is a high output pump, which delivers up to 2,000 gallons of sea water a minute; the pump can be brought up to maximum output in only one minute after turning on the power source, a small Allison gas turbine engine. The module also contains hose, a foam nozzle and a spray nozzle, three sets of protective clothing for firefighters, and fuel for three hours operation. Designed to be assembled without special tools, the module can be set up for operation in less than 20 minutes.

Helicopter transportability saves time either by direct air delivery of the module to the fire locale or by delivery to the deck of a ship already en route to the scene. The airlift capability makes feasible broader use of the module beyond the Coast Guard application, for example, firefighting in forests or other land areas adjacent to water. Where road delivery is possible, the module can be mounted on a trailer or a light truck as in the Firefly system pictured at the top of the page. The unit is also adaptable

to non-firefighting applications requiring a small, mobile, high performance pumping system—emergency water removal, for example.

Module development is being directed by NASA's Marshall Space Flight Center, which acquired extensive experience from space projects involving high-capacity rocket engine pumps, lightweight materials and compact packaging. Marshall's contractor for design and construction of the module is Northern Research and Engineering Corporation, Cambridge, Massachusetts. Northern Research is working with Aviation Power Supply, Inc., Burbank, California, to develop the Firefly system, shown undergoing test above. Firefly is a commercial version of the NASA/Coast Guard module which uses the same pump and other components.

USOE SMOKE DET CONT
ALARM
ALARM LEVEL
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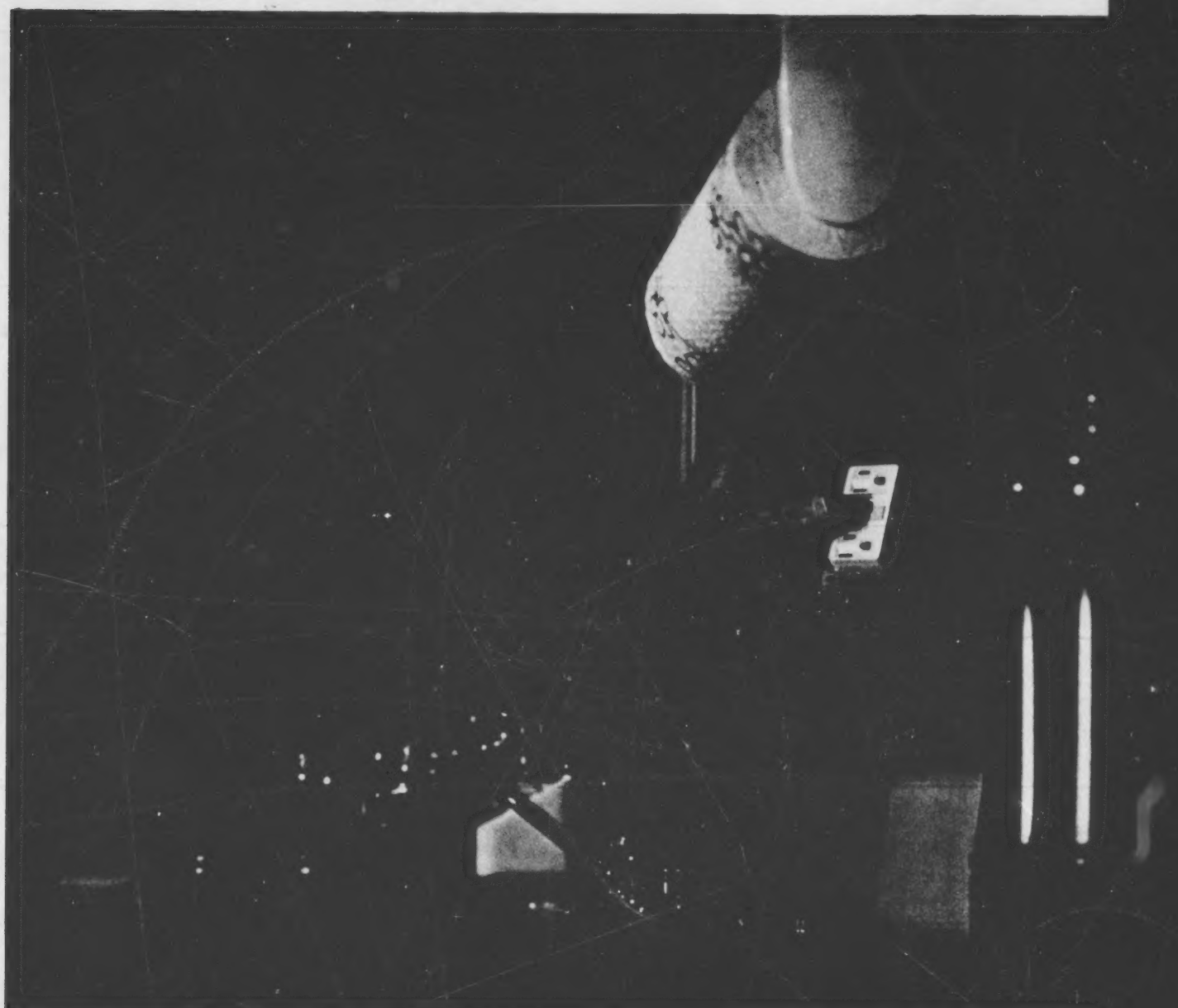
Shock Prevention The electrician pictured is installing a General Electric Ground Fault Interrupter (GFI), a device which provides protection against electrical shock in the home or in industrial facilities. Shocks due to defective wiring in home appliances or other electrical equipment can cause severe burns, even death. As a result, the National Electrical Code now requires GFIs in all new homes constructed.

This particular type of GFI employs a sensing element which derives from technology acquired in space projects by SCI Systems, Inc., Huntsville, Alabama; producer of sensors for GE and other manufacturers of GFI equipment. The sensor is based on the company's experience in developing miniaturized circuitry for space telemetry and other spacecraft electrical systems; this experience enabled SCI to package interruptor circuitry in the extremely limited space available and to produce sensory devices at practicable cost.

The tiny sensor measures the strength of the electrical current and detects current differentials that indicate a fault in the functioning of an electrical system. The sensing element then triggers a signal to a disconnect mechanism in the GFI, which cuts off the current in the faulty circuit.



Intruder Detector The shadowy prowler is attempting a break-in, unaware that his presence has already been detected and reported by the device in the lower left corner of the photo. It is part of a three-element Intruder Detection System developed by NASA's Ames Research Center from technology acquired in the Apollo lunar exploration program.

Apollo astronauts left behind on the moon small portable seismic (shock) detectors to record subsurface vibrations and transmit to Earth data on the moon's density and thickness. A similar seismic detector is the key component of the Intruder Detection System.

Encased in a stainless steel tube, the detector is implanted in the ground outside the facility being protected—home, bank, industrial or other facilities. The vibration-sensing detector picks up the footstep of anyone within a preset range. The detector is connected by cable to the transmitter, which relays the warning to a portable radio receiver. The radio alerts plant guards or home occupants by emitting an audible tone burst for each footstep.

For large industrial facilities, the detector's range can be as much as 260 feet. It would be set to shorter range for home use, so that the sensor would not pick up ordinary sidewalk traffic. In either plant or home use, the system could be tied in to the alert station of a municipal or commercial protection agency. It also has applicability to wildlife research.

NASA has granted licenses to two manufacturers for commercial production of the system.

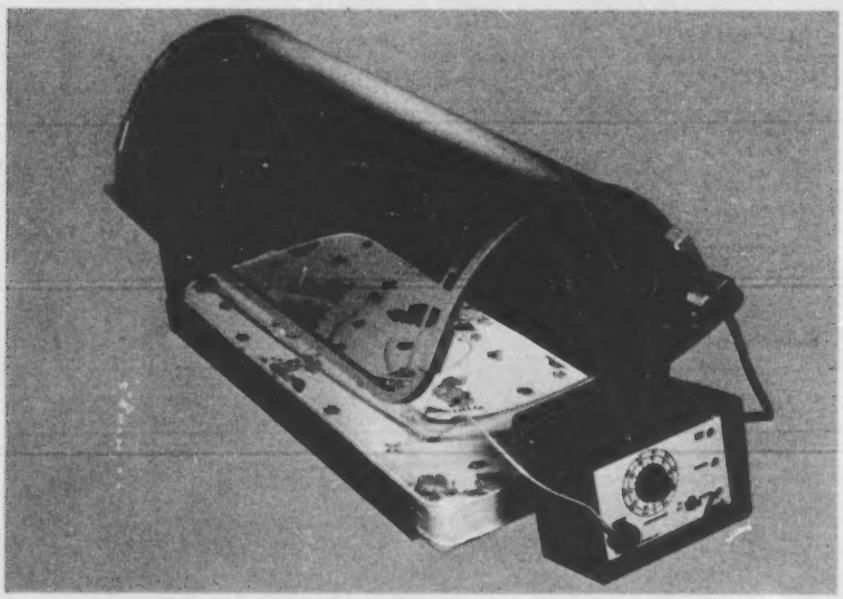
Representative of many spinoff innovations in health and medicine are hospital aids for assuring patient warmth, essential to infant care and treatment of burn victims

The Golden Canopies

Getting born is a difficult experience. Emerging from the warmth and security of the womb, the newborn infant is thrust into a totally new environment fraught with hazard. Medical experts say that the most critical period of an infant's early life is the first six to 12 hours after birth.

Nature, of course, equips the newborn to survive and the vast majority of babies enter the world with little or no trouble. But many are born weak, sickly or prematurely; even infants born healthy may develop post-delivery distress, such as breathing problems. In the U.S. alone, thousands die annually of respiratory problems associated with birth.

Widely used in post-delivery hospital care, this Infant Radiant Warmer is an offshoot of aerospace-developed technology in heated transparent materials. The canopy, which has a film of electricity-conducting gold, emits uniform, controlled radiant heat for warming a cradled infant without noise or burn hazard.



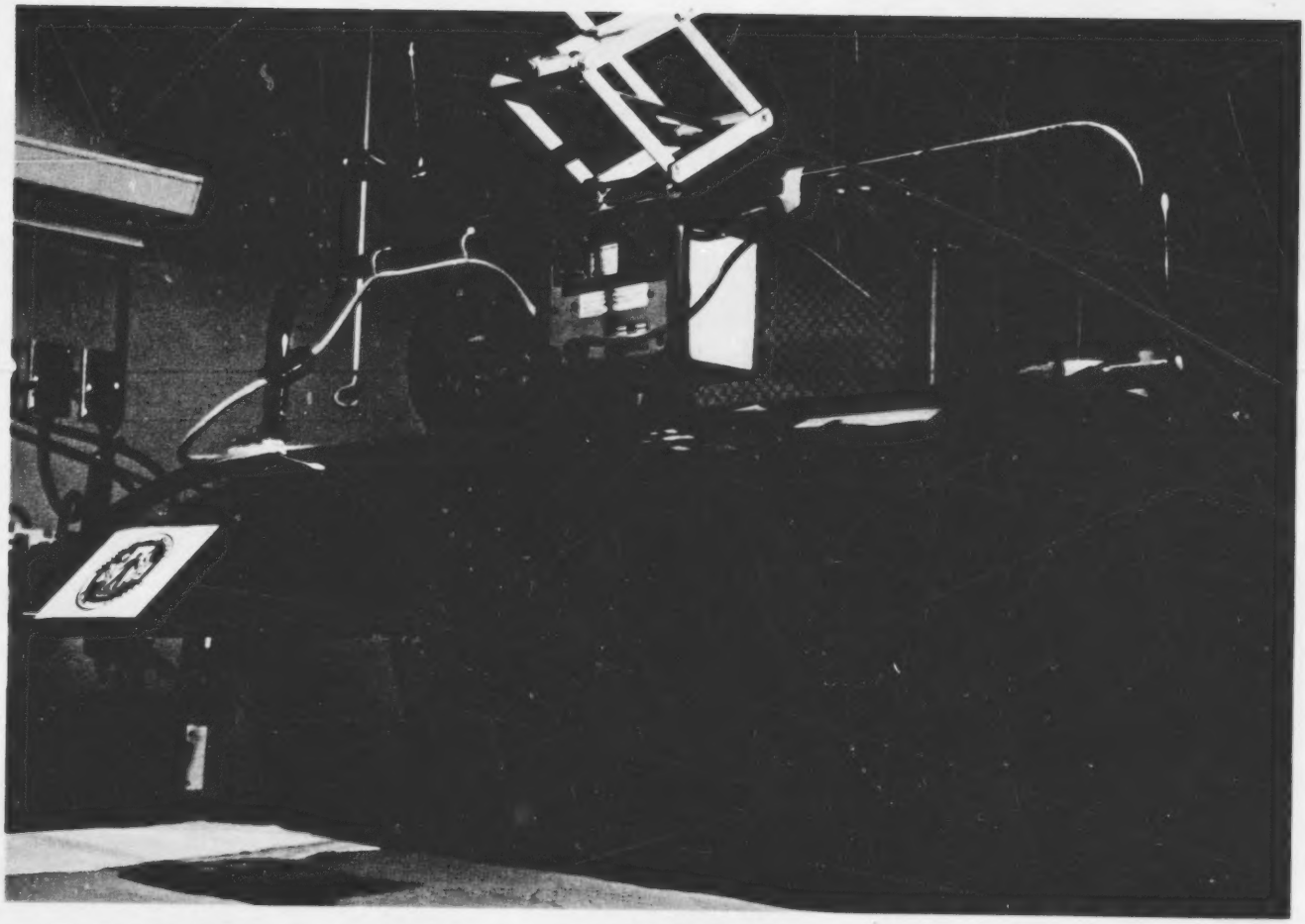
Working to combat the infant mortality rate, hospitals are continually upgrading delivery room and nursery care techniques. Many have special procedures and equipment to protect infants during the "period of apprehension," the critical six to 12 hours after delivery. One such item of equipment is an aerospace spinoff called the Infant Radiant Warmer, a "golden canopy" which provides uniform, controlled warmth to the infant's cradle. Warmth is vitally important to all newborns, particularly premature babies; they lose heat more rapidly than adults because they have greater surface area in comparison with body mass.

The cradle warmer is based on technology in heated transparent materials developed by Sierracin Corporation, Sylmar, California. The original application was in heated faceplates for the pressure suit helmets worn by pilots of an Air Force/NASA reconnaissance and weather research plane. Later, Sierracin advanced the technology for other applications, among them the cockpit windows of the NASA X-15 supersonic research vehicle and the helmet faceplates of Apollo astronauts. Adapting the technology to hospital needs, Sierracin teamed with Cavitron Corporation, Anaheim, California, which produces the cradle warmer and two other systems employing Sierracin's electrically-heated transparencies.

Widely used for routine post-delivery care and post-operative recovery, the cradle warmer is a canopy atop the infant's bassinet. The canopy is composed of laminated layers of transparent plastic which encase a thin film of gold called Intrex•. This coating is electrically conductive; when energized by electricity, the canopy emits low energy radiant heat over the infant's entire body.

A Cavitron-designed feature is a skin sensor which allows temperature control adjusted precisely to each baby's individual needs. The cradle warmer has no noise-producing element for heat generation, and there is no burn hazard to infant or nurse. The radiant warmer offers the additional advantage of total visibility. Since blankets are unnecessary, the baby lies naked in its cradle and the transparent canopy permits constant observation for changes of color or other indications of distress.

•Registered trademark, Sierracin Corporation



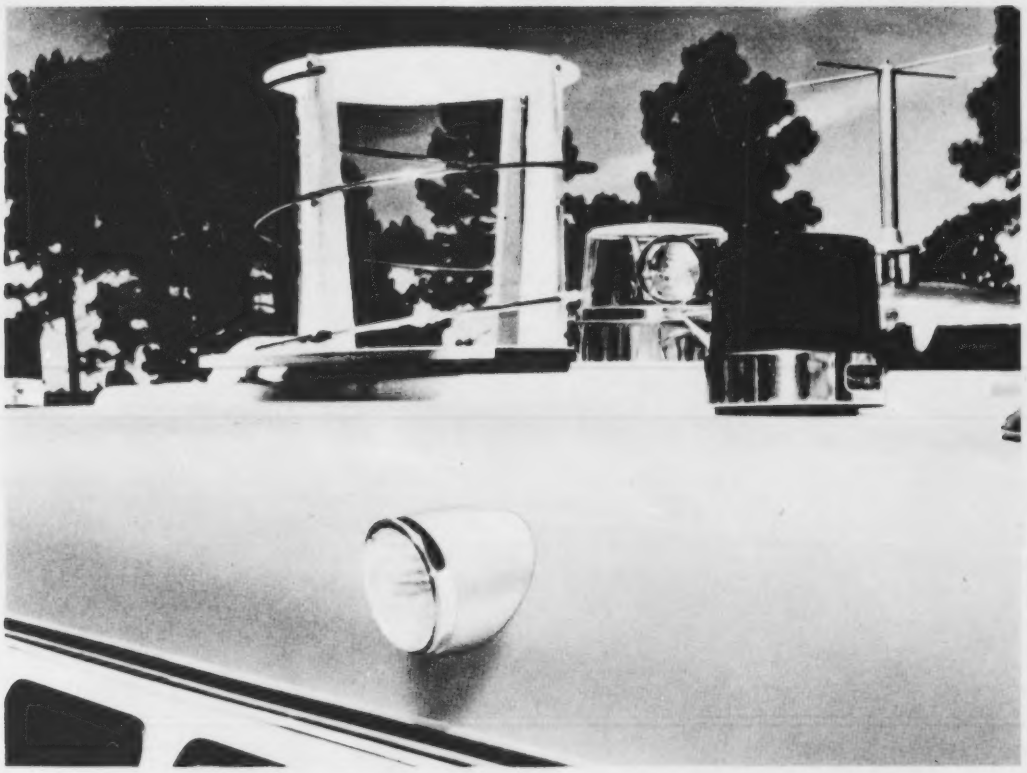
The Apollo Radiant Warmer, another application of heated transparencies, delivers essential warmth to burn patients more efficiently than previous methods and aids more effective treatment.

The heated transparency is also a feature of a new Sierracin-Cavitron product, introduced last year, the Stanford Transport-Incubator System. Developed by a team of medical and engineering personnel at Stanford University Medical Center, this unit meets a need for transporting seriously ill infants by airplane or ambulance to a specialized care facility.

The battery-powered portable incubator is an intensive care system consisting of three modules, one of them a transparent radiant warming hood that encloses the cradle. A monitoring module displays readings of heart rate, respiration, blood pressure and other bodily functions. A therapy module provides capabilities for ventilation, air-oxygen blending, fluid removal or infusion of fluids. Exclusive of batteries, the whole system weighs less than 50 pounds.

The Sierracin-Cavitron team produces a third application of heated transparency technology: the Apollo Radiant Warmer, a system designed specifically for the burn patient. An important matter in burn treatment is keeping the patient warm to counter hypothermia, a state of low body temperature characteristic of serious burns. Sheets and blankets cannot be allowed to come in contact with injured areas, so it was formerly necessary to suspend coverings over hoops encircling the patient's bed. Even so, burn victims complained of cold. The problem involves more than discomfort; shivering uses up large amounts of energy, energy needed to fight infection and to renew damaged cells. Energy expenditure also causes unwanted weight loss.

The Apollo Radiant Warmer, an over-bed canopy that works like the cradle warmer, eliminates the need for hoops and blankets. It provides a controlled thermal environment which contributes to more effective treatment by significantly reducing shivering and energy expenditure. In some instances, using physicians say, it is literally a life saver.



Heart Monitoring by Satellite The ambulance antenna shown is a specially designed system that allows satellite-relayed two-way communications between a moving emergency vehicle and a hospital emergency room. It is a key component of a demonstration program aimed at showing how emergency medical service can be provided to people in remote rural areas. Satellite communication permits immediate, hospital-guided treatment of heart attacks or other emergencies by ambulance personnel, saving vital time when the scene of the emergency is remote from the hospital. If widely adopted, the system could save tens of thousands of lives annually in the U.S. alone, medical experts say.

The problem in conventional communication with rural areas is the fact that radio signals travel in line of sight. They may be blocked by tall buildings, hills and mountains, or even by the curvature of the Earth, so signal range is sharply limited. Microwave relay towers could solve the problem, but a complete network of repeater towers would be extremely expensive. The satellite provides an obstruction-free relay station in space.

An example of the satellite's utility was a test in which voice and data signals were relayed between an ambulance in rural Alabama and Forrest County General Hospital in Hattiesburg, Mississippi, some 200 miles away. Equipped with a battery-powered Telecare II Advanced Life Support Unit (also an aerospace spinoff) the ambulance team transmitted a simulated heart attack victim's electrocardiagram. The signals were beamed to NASA's ATS-3 satellite, operating in stationary orbit 22,300 miles above Ecuador, thence to the emergency room of Forrest General. The space-relayed EKG, together with two-way conversation capability, enabled a hospital physician to advise ambulance personnel as to life-saving prehospital treatment. The antenna played an important part. Designed for low height above the ambulance roof and sufficient mechanical strength to withstand road speeds up to 70 miles per hour, it is an omni-directional antenna that requires no operator adjustment as the ambulance speeds toward the hospital.

The demonstration was a cooperative project involving NASA's National Space Technology Laboratories in Mississippi; the Mississippi governor's Office of Science and Technology; and the Southern Regional Medical Consortium, comprised of Forrest County General Hospital, the University of Southern Mississippi, and the Southeast Mississippi Air Ambulance District. The antenna was designed and built by General Electric Company's Corporate Research and Development Center, Schenectady, New York.

Emergency Communications Console NASA has applied its communications equipment expertise to development of a communications console that provides, in a compact package only slightly larger than an electric typewriter, all the emergency medical services communications functions needed for a regional hospital. A prototype unit, built by Johnson Space Center, has been installed in the Odessa (Texas) Medical Center Hospital. The hospital is the medical control center for the 17-county Permian Basin Emergency Medical System in west Texas.

The console project originated in response to a request to NASA from the Texas governor's office, which sought a better way of providing emergency medical care in rural areas. Because ambulance travel time is frequently long in remote areas of west Texas, it is important that treatment begin at the scene of the emergency rather than at the hospital emergency room. A radio and telephone system linking ambulance emergency technicians and hospital staff makes this possible. But earlier equipment was complex, requiring specialized operators. A highly reliable system was needed to minimize breakdowns and provide controls of utmost simplicity, so that the system could be operated by physicians and nurses rather than by communications specialists.

The resulting console has both radio and telephone sections. With the radio equipment, hospital personnel can communicate with ambulance drivers and paramedics, receive incoming electrocardiagrams, consult with other hospitals, page hospital staff and set up a radio-to-telephone "patch." The telephone portion of the system includes a hotline from the Permian Basin Emergency Medical Service's resource control center, an automatic dialer for contacting special care facilities in the Permian Basin network, a hospital intercom terminal and a means of relaying cardioscope displays and other data between hospitals. The integrated system also provides links with local disaster and civil defense organizations and with emergency "Dial 911" control points.

Patient Monitoring In photo above, the electrocardiogram of a hospitalized patient is being transmitted by telemetry. Widely employed in space operations, telemetry is a process wherein instrument data is converted to electrical signals and sent to a receiver where the signals are reconverted to usable information. In this instance, heart readings are picked up by the electrode attached to the patient's body and delivered by wire to the small box shown, which is a telemetry transmitter. The signals are relayed wirelessly to the console in the background, which converts them to EKG data. The data is displayed visually and recorded on a printout; at the same time, it is transmitted to a central control station (upper photo) where a nurse can monitor the condition of several patients simultaneously.

The Patient Monitoring System was developed by SCI Systems, Inc., Huntsville, Alabama, in conjunction with Abbott Medical Electronics, Houston, Texas. In developing the system, SCI drew upon its extensive experience as a NASA contractor. The company applied telemetry technology developed for the Saturn launch vehicle and the Apollo spacecraft; instrumentation technology developed for heart, blood pressure and sleep monitoring of astronauts aboard NASA's Skylab long duration space station; and communications technology developed for the Space Shuttle.

Telemetry reduces the time needed for personal attendance by nurse or physician and permits round-the-clock monitoring with minimal inconvenience to the patient. An ambulatory patient can walk around, unencumbered by wires, while his EKG is continuously recorded; he can even leave his hospital room and move as far as 400 feet without interrupting the data relay. For intensive care situations where monitoring a number of other vital signs is necessary, SCI has developed a family of clinical instruments which can be employed in the Patient Monitoring System.

Automated Blood Pressure Measurement The Vital-2 unit pictured is a semi-automatic device that permits highly accurate blood pressure measurement, even by untrained personnel. Developed by Meditron Instrument Corporation, Milford, New Hampshire, it is based in part on NASA technology found in a similar system designed for automatic monitoring of astronauts' blood pressure.

Vital-2 is an advancement over the familiar arm cuff, dial and bulb apparatus customarily used for blood pressure checks. In that method, the physician squeezes the bulb to inflate the arm cuff, which restricts the flow of blood through the arteries. As he eases the pressure on the arm, he listens—through a stethoscope—to the sounds of resumed blood flow as the arteries expand and contract. Taking dial readings related to sound changes, he gets the systolic (contracting) and diastolic (expanding) blood pressure measurements. The accuracy of the method depends on the physician's skill in interpreting the sounds. Hospitals sometimes employ a more accurate procedure, but it is "invasive," involving insertion of a catheter in the artery.

For monitoring astronauts in space, NASA sought a compact, automatic system capable of high accuracy and reliability, yet non-invasive and not requiring interpretive skill. Johnson Space Center and Technology, Inc., a contractor, developed an electronic sound processor that automatically analyzes blood flow sounds to get both systolic and diastolic measurements. Meditron obtained a license to use the NASA-patented technology and incorporated a variation of the diastolic measurement technique in developing Vital-2.

Vital-2 weighs only six pounds and can be carried anywhere. It operates either on its own rechargeable battery or by plugging in to a standard outlet. The system requires positioning and inflation of the arm cuff, but after that it operates automatically. The interpretation is handled by its electronic equipment, and the blood pressure readings appear automatically on a digital display. Because it is accurate, reliable and non-invasive, it has proved attractive to the medical profession and Meditron has sold several hundred units to hospitals, medical screening clinics, physicians and anesthesiologists.

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Infant Transport Monitoring The photo sequence illustrates the movement of an ill infant to a special care hospital by means of a new Pediatric Monitoring and Transport System, in which NASA technology and technical assistance are being applied to an urgent medical problem. Development of the system is a collaborative effort involving several organizations, principally NASA Ames Research Center and Children's Hospital Medical Center, Oakland, California.

Key to the system's efficacy is a custom-designed ambulance-to-hospital and hospital-to-hospital communications network, including two-way voice capability and space-derived biotelemetry; it allows a specialist at the destination hospital to monitor continuously the vital signs of the patient during transit.

Premature babies and others who become ill soon after birth require intensive care and treatment most community hospitals cannot provide; they lack the specially-trained physicians and nurses and the expensive equipment needed. Movement of infants from outlying areas to intensive care nurseries such as Oakland's Children's Hospital Medical Center, which handles 50 critically ill newborns a month, may take hours by ground ambulance; even airplane and helicopter transport can be lengthy. Medical experts say that infants' survival frequently depends on efficient transport management and en route care.

With the Pediatric Monitoring and Transport System, the baby is under constant direct and remote supervision throughout the trip. The multifaceted system includes special preparations at the originating hospital; a new incubator (far right photo) specifically designed for this application; a specially-trained intern and nurse on the transport vehicle; a Telecare portable biotelemetry unit (red box in top photo), a spinoff from physiological monitoring of astronauts in space; an ambulance-mounted or airborne transmission system for voice or telemetry signals; microwave towers for relaying communications; and a Neonatal (newborn) Monitoring Base Station at Children's Hospital Medical Center (photo at right). The latter is staffed by a neonatal specialist physician, who has radio and telephone contact with the transport vehicle, the originating hospital, and the Alameda County Medical Communications Coordinating Center.

By means of specially-designed, non-invasive electrodes attached to the infant's body, vital data—for example, electrocardiogram, respiration and temperature—is sent continuously to Children's Hospital Medical Center. It is displayed on a console and also recorded on cassettes and a strip chart recorder. The system provides the monitoring neonatologist essential information for prescribing en route care measures or emergency treatment if the infant's condition worsens during transit. The monitoring process continues even after arrival at the hospital, during surgery or intensive care.

Ames Research Center is applying NASA-developed technology, particularly bioinstrumentation, and providing technical assistance in the evaluation of telemetry and other systems. Ames is being helped by Johnson Space Center, under whose supervision the Telecare unit was originally developed. In addition to Children's Hospital Medical Center, other participants include Telecare, Inc., Houston, Texas; Perinatal Systems, Inc., Tucson, Arizona, which contributed the equipment and installation expertise for

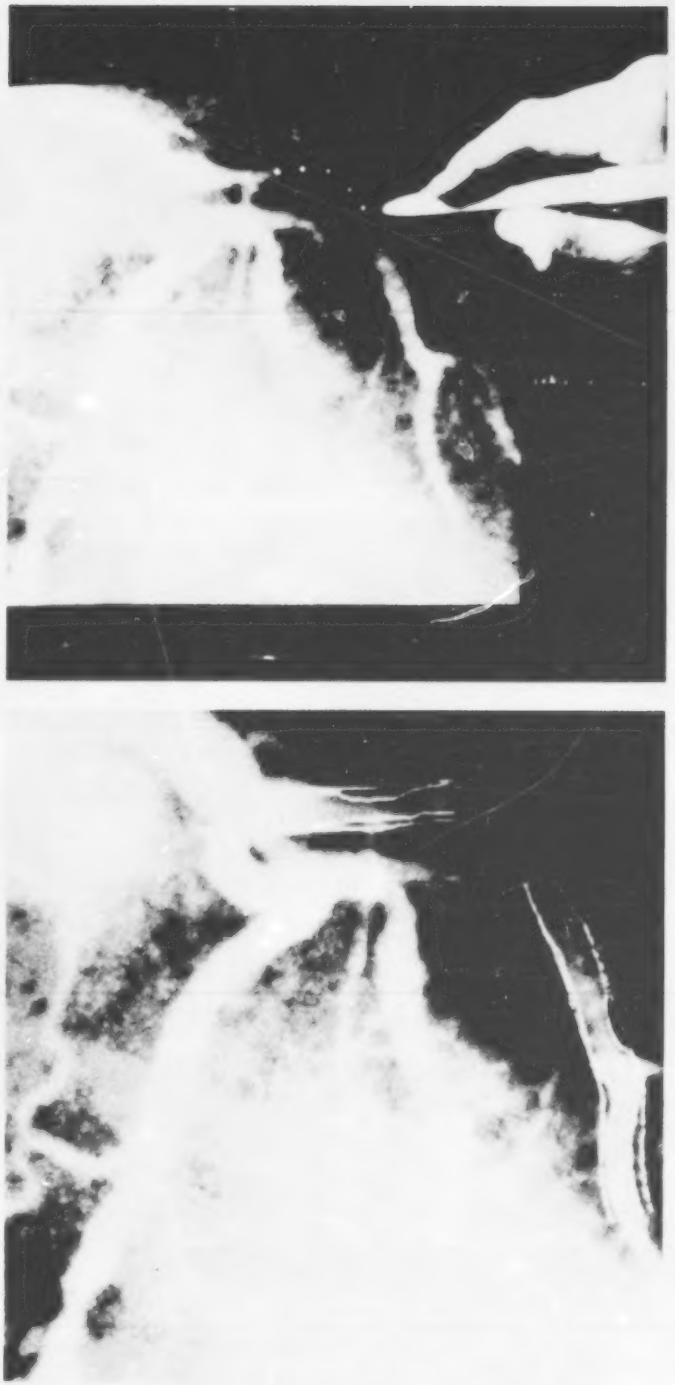
the central monitoring station; and the Bay Area Emergency Medical Services Council. Funding was provided by NASA, the Department of Health, Education and Welfare, and Alameda County.

The system went into operation late last year and it is planned to extend the service to other hospitals in northern California.

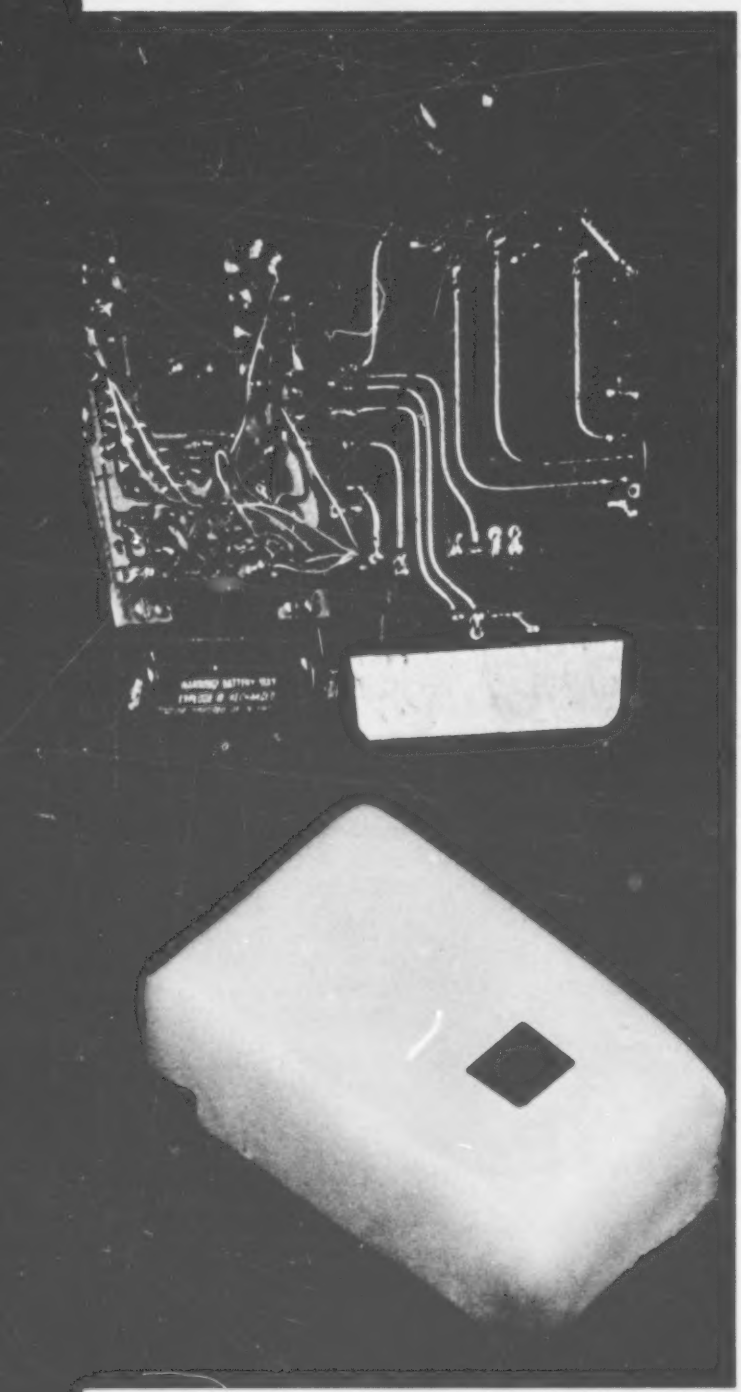
Medical Image Analysis Facility To improve the quality of photos sent to Earth by unmanned spacecraft, NASA's Jet Propulsion Laboratory (JPL) developed a computerized image enhancement process that brings out detail not visible in the basic photo. JPL is now applying this technology to biomedical research in its Medical Image Analysis Facility, which employs computer enhancement techniques to analyze x-ray films of internal organs, such as the heart and lung.

A major objective is study of the effects of stress on persons with heart disease. In animal tests, computerized image processing is being used to study coronary artery lesions and the degree to which they reduce arterial blood flow when stress is applied. The photos illustrate the enhancement process. The upper picture is an x-ray photo in which the artery (dotted line) is barely discernible; in the post-enhancement photo at right, the whole artery and the lesions along its wall are clearly visible. The Medical Image Analysis Facility offers a faster means of studying the effects of complex coronary lesions in humans, and the research now being conducted on animals is expected to have important application to diagnosis and treatment of human coronary disease.

Other uses of the facility's image processing capability include analysis of muscle biopsy and pap smear specimens, and study of the microscopic structure of fibroprotein in the human lung. Working with JPL on experiments are NASA's Ames Research Center, the University of Southern California School of Medicine, and Rancho Los Amigos Hospital, Downey, California.



Hearing Aid Tester Hearing aids often develop malfunctions that are not detected by the wearer. This is particularly true when the wearers are school-age children. Studies of selected groups showed that from 30 to more than 50 percent of schoolchildren were not getting adequate benefit from their hearing aids because of unrecognized malfunctions, usually low or dead batteries. This can be serious because hearing impairment retards a child's educational progress.



NASA technology incorporated in the Hearing Aid Malfunction Detection Unit (HAMDU), the device pictured, is expected to provide an effective countermeasure to the childrens' hearing aid problem. A patent license has been awarded to a minority-owned firm, Hopkins International Company, a subsidiary of H. H. Aerospace Design Co., Inc., Elmford, New York. The company plans early commercial availability of its version of the device.

Worn by the user as an adjunct to the hearing aid, HAMDU is a miniaturized, battery-powered system which monitors the hearing aid's operation. Twice every hour, HAMDU's electrical circuitry performs a check of the hearing aid's battery, amplifier and receiver cord. If, for example, battery voltage is too low, or if the amplifier's sound signal is distorted, the circuitry triggers an indicator light. In classroom use, a teacher would immediately be alerted that the child's hearing aid was malfunctioning or was turned off by accident or design.

HAMDU operates continuously while the hearing aid is in use. Relatively inexpensive, it eliminates the need for periodic inspections requiring removal of the hearing aid from the child. The automatic check takes only half a second and has no effect on hearing aid performance.

Johnson Space Center and Martin Marietta Aerospace-Denver built prototype units which were thoroughly tested in the laboratory and in actual use by schoolchildren. The latter tests (photo) were conducted at the Callier Center of the University of Texas-Dallas. Several children wore the HAMDU units during classroom instruction and malfunctions were induced in their hearing aids. In 200 hours of schoolroom evaluation, HAMDU reported all malfunctions within an hour of their occurrence and triggered no false alarms.

A pair of effective exercising devices highlight an array of aerospace technology transfers to the fields of sports and recreation

Body-Building Boons From Apollo

Members of the National Football League's Oakland Raiders work out with the Apollo Exerciser. The device is used by 82 professional sports teams, more than 1,000 colleges and some 10,000 high schools.

Aboard Apollo 7, the first manned flight of the Apollo program, astronaut Donn Eisele reported that his lower abdominal muscles ached somewhat from "floating around in the seated position." But, he told mission control, he felt a lot better after using the Exer-Genie.

Crewmates Walter Schirra and Walter Cunningham concurred that the exercising device was a "good deal." "One of the best 'spacey' things we've had in years," Schirra added.

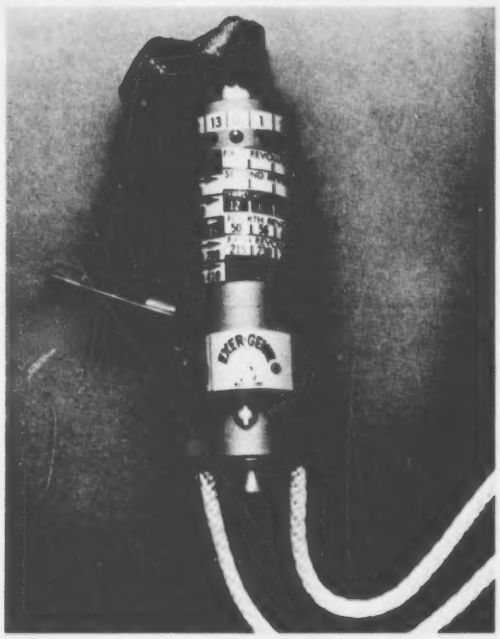
The Exer-Genie they were talking about was an innovative exerciser based on the principle of muscle strengthening through controlled resistance. Hooked to the spacecraft wall, it enabled the astronauts to keep various muscles toned by rope-pulling from several angles and positions. It proved an answer to a problem that had concerned NASA for some time.

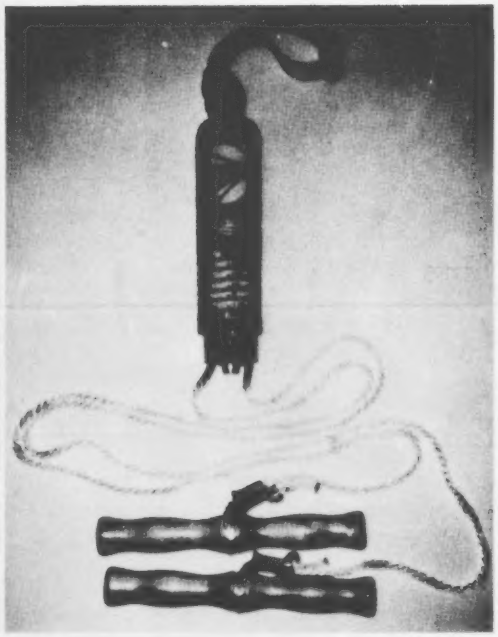
The problem was the effect on the human body of long duration weightlessness and confinement without exercise. The Apollo program contemplated flights of eight to 13 days. Research by Johnson Space Center indicated that lengthy activity restriction and exposure to zero gravity could induce loss of calcium and bone density, possibly metabolic and cardiovascular problems. These findings inspired further research on offsetting dietary measures, together with a quest for some effective system of exercise.

Normal means of exercise were not applicable, due to weightlessness and the limited space within Apollo. Bulky equipment was out, since there were many other items competing for space and weight allowances. Johnson Space Center came up with Exer-Genie, developed by Exer-Genie, Inc., Fullerton, California. The device weighed less than two pounds and took up very little room, yet it permitted a wide range of resistive exercises. It proved effective and was used on subsequent Apollo missions. The astronauts' use of this exerciser generated publicity that has spurred sales of Exer-Genie.

The Exer-Genie program utilizes familiar types of exercise, such as isometrics (pushing or pulling against an immovable object) and isotonics (motive exercises such as calisthenics or weight lifting) but with the important added factor of controlled resistance. The device is an arrangement of hand grips and nylon cord wrapped around an aluminum shaft. Controlled friction determines the resistance and the user can set the amount of resistive force to his own physical conditioning needs.

Since Apollo days, the Exer-Genie and a similar device called the Apollo Exerciser have found wide acceptance among professional, collegiate and high school athletic teams, and among the growing number of individuals interested in physical fitness. These devices are efficient and economical replacements for conventional conditioning equipment and extremely versatile, allowing more than 100 basic exercises for shaping up specific muscle groups.





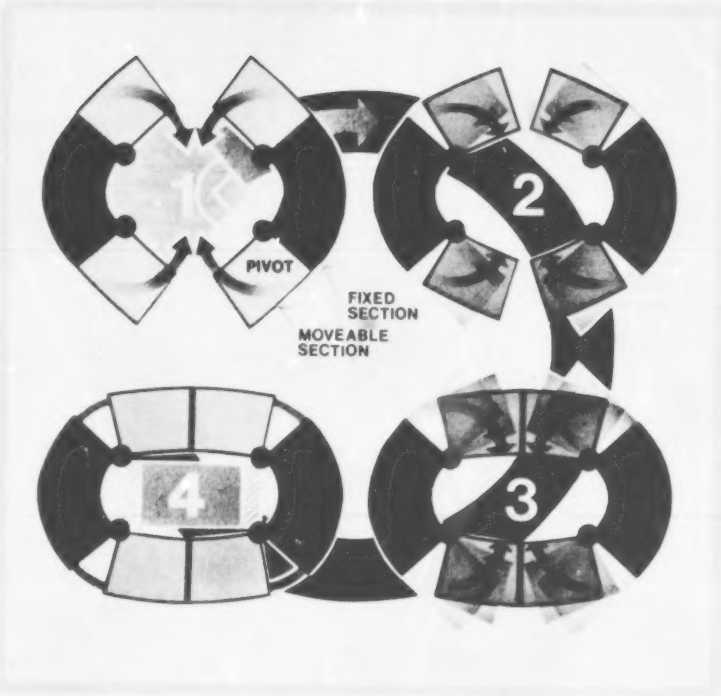
Exer-Genie (left) and the Apollo Exerciser, novel physical conditioning aids of the type used by Apollo astronauts in space. Within the cylinders, the nylon cords rotate around a shaft, developing controlled resistance for more effective body-building.

One of the more important advantages is time-saving, since time is a deterrent to many who might otherwise engage in a conditioning program. Advocates of "isokinetics," as some call the controlled resistance exercise method, say that 12 to 15 minutes of daily effort provides the equivalent in cardiovascular improvement and general physical toning of 40-60 minutes daily work in isometrics-isotonics.

Fitness Motivation Institute of America, San Jose, California, markets the Apollo Exerciser. Like Exer-Genie, the Institute sells to professional and amateur athletic groups, but its main thrust is at "the average, out-of-shape, overweight American," particularly businessmen who don't have the time for conventional exercising. The Institute offers its "Total Isokinetics" program to business firms, stressing the corporate advantages of improving conditioning, and especially building cardiovascular endurance, among the company's executives. It provides a package—including lectures, counseling and a course of training—tailored to a particular company's needs.

Exer-Genie and the Apollo Exerciser have made remarkable impacts on the physical fitness world in a relatively short time—and interest is still on the upswing.

Using the Exer-Genie, father and daughter demonstrate the teamwork approach employed in group conditioning. The Exer-Genie offers more than 100 basic exercises and variations.



Convertible Stadium Air flotation technology used in NASA's Apollo program has found an interesting application in Hawaii's Aloha Stadium near Honolulu. The stadium's configuration can be changed, by moving entire 7,000-seat sections on a cushion of air, for best accommodation of spectators and participants at different types of events.

In most stadiums, only a few hundred seats can be moved, by rolling sections on wheels or rails. At Aloha Stadium, 28,000 of the 50,000 seats can be repositioned for better spectator viewing and, additionally, for improved playing conditions. For example, a stadium designed primarily for football may compromise the baseball diamond by providing only a shallow outfield. Aloha's convertibility allows a full-size baseball field as well as optimum configurations for many other types of sports and special events. The photos show examples.

The stadium owes its versatility to air flotation technology developed by General Motors. Its first large-scale application was movement of huge segments of the mammoth Saturn V moonbooster during assembly operations at Marshall Space Flight Center.

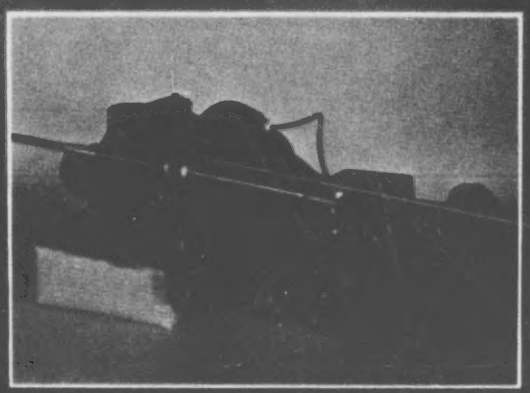
The air movement contractor for Aloha Stadium is Rolair Systems, Inc., Santa Barbara, California, a company formed by former General Motors employees familiar with the technology. Rolair was licensed by GM to produce and market the air flotation system for moving heavy objects. It is widely used in industrial applications and is also employed in movement of heavy components of NASA's Space Shuttle and the Boeing 747.

Aloha Stadium's design includes two permanently-fixed sections and four movable sections, each of the latter weighing three million pounds. Located under each section are 26 Rolair transporters, into which streams of compressed air are directed to inflate a series of elastic, doughnut-like diaphragms. Inflation of the diaphragms lifts the entire massive steel structure about an inch off the ground. Compressed air bleeds out of the diaphragms creating a film of air on which the grandstand floats, nudged into its new position by the transporter. With this lubricating air film, a force of only one pound is needed to move a thousand pounds. Compressed air blowing and transporter operation is directed from four control consoles, one for each movable section; a single operator can reposition a section in just half an hour.

Marine Jet The marine turbine pump pictured is the Jacuzzi 12YJ, a jet propulsion system for pleasure or commercial boating. Its development was aided by a NASA computer program made available by the Computer Software Management and Information Center (COSMIC) at the University of Georgia.

The manufacturer—Jacuzzi Brothers, Incorporated, Little Rock, Arkansas—used COSMIC's Computer Program for Predicting Turbopump Inducer Loading, which enabled substantial savings in development time and money through reduction of repetitive testing.

The 12YJ is a technical advance in that it offers very high propulsive thrust in relation to power output. Powered by a conventional marine engine, the 12YJ operates in a manner similar to an airplane jet engine, except that it uses water rather than air as the propulsive medium. The turbine pump takes in water through an intake grill in the bottom of the boat and expels it at high velocity through a stern nozzle, creating a powerful propulsive thrust. The system offers exceptional control and maneuverability, whether at docking speed or wide-open throttle. The 12YJ is one of a number of Jacuzzi jets used to power a variety of marine craft from small pleasure boats to Navy combat vessels.



RoadRover

Heated Goggles The electrically heated ski goggles shown incorporate technology similar to that once used in Apollo astronauts' helmet visors, and for the same reason—providing fogfree sight in an activity that demands total vision.

Defogging is accomplished by applying heat to prevent moisture condensation. Electric heat is supplied by a small battery built into the goggles' headband. Heat is spread across the lenses by means of an invisible coating of electrically conductive metallic film.

The goggles were introduced to the market last fall. They were designed by Sierracin Corporation, Sylmar, California, specialists in the field of heated transparent materials. The company produces heated windshields for military planes and for such civil aircraft as the Boeing 747, McDonnell Douglas DC-10 and Lockheed L-1011 TriStar. The ski goggle lenses are manufactured at Sierracin's Sylmar Division and the product is marketed through Smith Goggle Company, Sun Valley, Idaho.

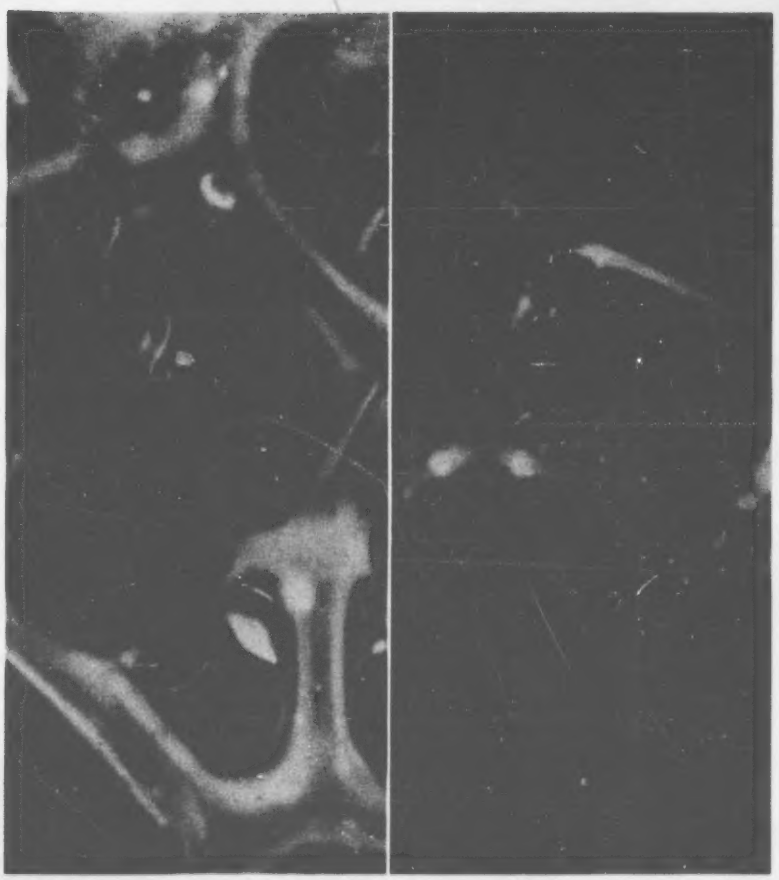
Trash Compactor A boon to operators of boats and recreational vehicles is a new trash compactor that needs no electrical power. Originally developed for use aboard the Space Shuttle Orbiter, the device shown at left has hand-operated ratchets which drive a pressure plate to crush the material in the liner bag. The compactor has a compressive force of 2,000 pounds, more than ample to flatten food cans. Its energy-less operation may also attract household kitchen use.

The compactor was developed by Nelson & Johnson Engineering, Inc. Boulder, Colorado under contract to Johnson Space Center. NASA granted the firm a waiver of rights to the invention under its policy of encouraging contractors to develop spinoff products. The compactor is now in the early production stage.

Among examples of aerospace technology application to consumer products is an innovative technique for producing a special type of plastic foam

Foam For Filtering

Like nature's honeycomb, foam is a structure of many-sided cells, apparently solid but actually only three percent material and 97 percent air. Foam is made by a heat-producing chemical reaction which expands a plastic material in a manner somewhat akin to the heat-induced rising of a loaf of bread.



In these microscopic views of plastic foam, the left photo shows "windows," thin membranes connecting the cell walls. The right photo illustrates the different structure formed by a patented Scott Foam Division process called "reticulation." The process removes the membranes, creating a completely open network which allows air to flow freely through the foam while dirt and other particles are caught by the cell strands.

The resulting structure of interconnected cells is flexible yet strong and extremely versatile in application.

Foam can, for example, be a sound absorber in one form, while in another it allows sound to pass through it. It can be a very soft powder puff material and at the same time a highly abrasive scrubber. A sampling of foam uses includes stereo speaker grilles, applying postage meter ink, filtering lawnmower carburetor air; deadening noise in trucks and tractors, applying cosmetics, releasing fabric softener and antistatic agents in home clothes dryers, painting, filtering factory heating and ventilating systems, shining shoes, polishing cars, sponge-mopping floors, acting as pre-operative surgical scrubbers—the list is virtually limitless.

The process by which foam is made produces "windows," thin plastic membrances connecting the cell walls. Windowed foam is used in many applications but for certain others—filtering, for example—it is desirable to have a completely open network. Scott Paper Company's Foam Division, Chester, Pennsylvania, improved a patented method of "removing the windows," to create an open structure that affords special utility in filtering applications. NASA technology contributed to Scott's improvement.

Under contract to Marshall Space Flight Center, Rockwell International prepared a manual detailing advanced techniques for cementing a variety of strain gages to many common engineering materials. A Scott engineer engaged in development of equipment for producing open structure foam

learned of the NASA technology and requested a technical support package. The information was used to install strain gages on a pressure vessel of the Scott-engineered "thermal reticulation" chamber and it was instrumental in reducing development time.

Reticulation, which means formation of an open network, is the process which fully opens the pores of the foam structure by removing the window-like membranes. This permits air to flow freely through the small apertures, while particles of dust or dirt adhere to the cell walls. That makes reticulated foam an effective filtering medium; it is used in air conditioners, humidifiers, home and commercial forced air furnaces, engine air filters, and a broad variety of other items manufactured in the appliance, automotive, medical equipment, consumer electronics, cosmetics and household products industries.

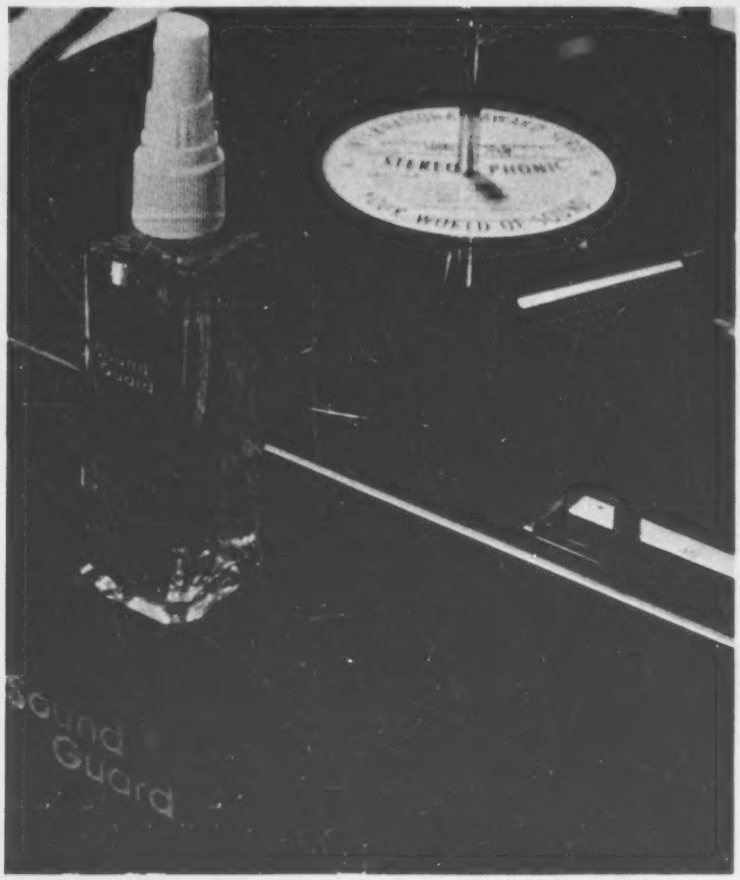
An assemblage of some of Scott Foam's consumer household and personal care products, some of which are made of reticulated foam.

Photo shows an assortment of Scott's reticulated foam filters used in auto, lawnmower, motorcycle and other recreational vehicle engines.

Sound Guard Lubrication technology originally developed for a series of NASA satellites has produced a commercial product for protecting the sound fidelity of phonograph records. Called Sound Guard, the preservative is a spray-on fluid that deposits a microscopically thin protective coating which reduces friction and prevents the hard diamond stylus from wearing away the softer vinyl material of the disc. It is marketed by the Consumer Products Division of Ball Corporation, Muncie, Indiana.

The lubricant technology on which Sound Guard is based originated with NASA's Orbiting Solar Observatory (OSO), an Earth-orbiting satellite designed and built by Ball Brothers Research Corporation, Boulder, Colorado, also a division of Ball Corporation. Ball Brothers engineers found a problem early in the OSO program: known lubricants were unsuitable for use on satellite moving parts that would be exposed to the vacuum of space for several months. So the company conducted research on the properties of materials needed for long life in space and developed new lubricants. They worked successfully on seven OSO flights and attracted considerable attention among other aerospace contractors. Ball Brothers now supplies its "Vac Kote" lubricants and coatings to both aerospace and non-aerospace industries and the company has produced several hundred variations of the original technology.

Ball Corporation expanded its product line to include consumer products, of which Sound Guard is one of the most recent. In addition to protecting record grooves, Sound Guard's anti-static quality also retards particle accumulation on the stylus. During comparison study by a leading U.S. electronic laboratory, a record not treated by Sound Guard had to be cleaned after 50 plays and the stylus had collected a considerable number of small vinyl particles. The Sound Guard-treated disc was still clean after 100 plays, as was its stylus.



Sound
Guard

Five Year Flashlight An ultra-reliable flashlight, initially developed for rescue signaling and utility use by NASA astronauts and military aircrews, has attracted a broad commercial market. Called the Five Year Light, it has a shelf life at least that long because there is no power drain on the batteries when the flashlight is not in use.

The NASA version of the light was developed under contract with Langley Research Center by ACR Electronics, Inc., now known as the Chromalloy Electronics Division of Chromalloy American Corporation, Hollywood, Florida. NASA wanted a light that had long shelf life and assured reliability in case it was needed in an emergency. Reliability was designed into the flashlight by means of a unique switch. Instead of the customary thumb-button, the Five Year Light is turned on by rotating its collar to make contact with the battery terminal; the turning motion wipes away any corrosion that might be present and makes contact virtually certain.

The Five Year Light available commercially is a repackaged version of the NASA light. It is sold for car, home, industrial, police, firefighting, recreational and a variety of other uses, and sales have topped two million units.

Bulb-Miser You probably have noticed that most light bulbs fail when you flick on the light switch. That's because the initial impact of the full current is too much for the cold filament. A new product called the Bulb-Miser* provides the answer to a problem for large quantity bulb users. It acts as a thermal shock absorber and lets the filament heat up slowly to prevent burnout. The result: an average increase in bulb life of 300 percent.

The Bulb-Miser was developed during NASA's Apollo program to protect the Saturn launch vehicle from electrical current surge. It is now being produced for the commercial market by Bulb-Miser, Inc., Houston, Texas.

Technically known as a "temperature compensating thermistor," the Bulb-Miser is a simple, inexpensive device which looks like a washer about the size of a quarter. It is slipped between bulb and socket and can be used with any incandescent bulb that screws into a standard socket. In addition to delaying burnout, the Bulb-Miser also offers some reduction of electrical energy. But the economy of the device goes beyond energy use or bulb cost; to big users of bulbs, it makes possible substantially lower maintenance labor costs. One field test involving an apartment complex showed that it took two men 30 man hours monthly to replace light bulbs; after Bulb-Miser installation only nine man hours a month were needed.

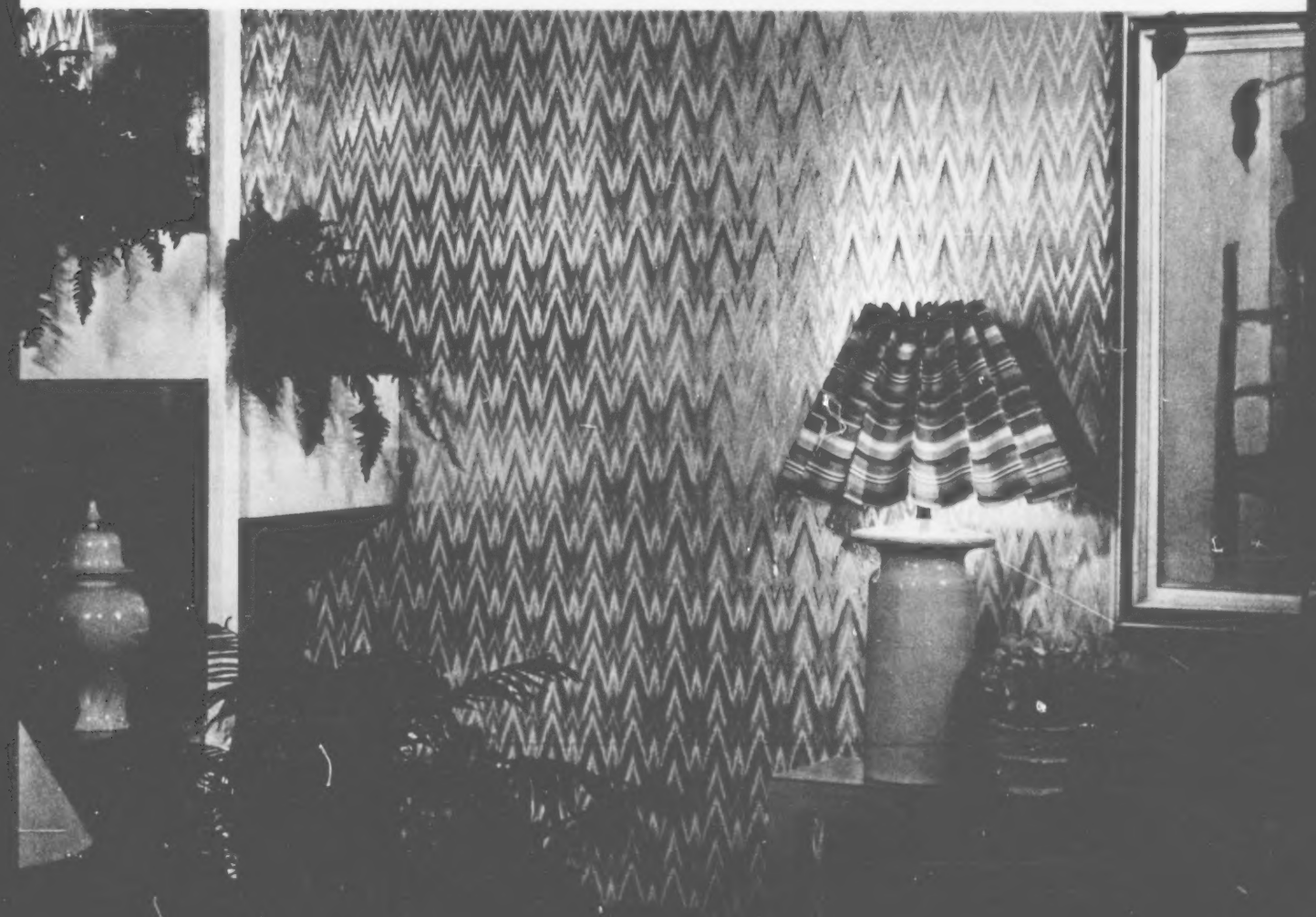
Bulb-Misers are used not only in private homes but also by hospitals, schools, hotels and motels, restaurants, banks and firms providing contract maintenance for large outdoor electric signs. The broadest use is in industrial facilities; the list of big companies which have purchased the Bulb-Miser reads like a Who's Who of American industry.

*Registered trademark, Bulb-Miser, Inc.

Wall Covering The attractive wall covering shown below is one of 132 styles in the Mirror Magic II line offered by The General Tire & Rubber Company, Akron, Ohio. The material is metallized plastic fabric, a spinoff from space programs.

Wall coverings are one of many consumer applications of aluminized plastic film technology developed for NASA by a firm later bought by King-Seeley Thermos Company, Winchester, Massachusetts, which now produces the material. The original NASA use was in the Echo 1 passive communications satellite, a "space balloon" made of aluminized mylar; the high reflectivity of the metallized coating enabled relay of communications signals from one Earth station to another by "bouncing" them off the satellite. The reflectivity feature also made the material an extremely efficient insulator and it was subsequently widely used in the Apollo program for such purposes as temperature control of spacecraft components and insulation of tanks for fuels that must be maintained at very low temperatures.

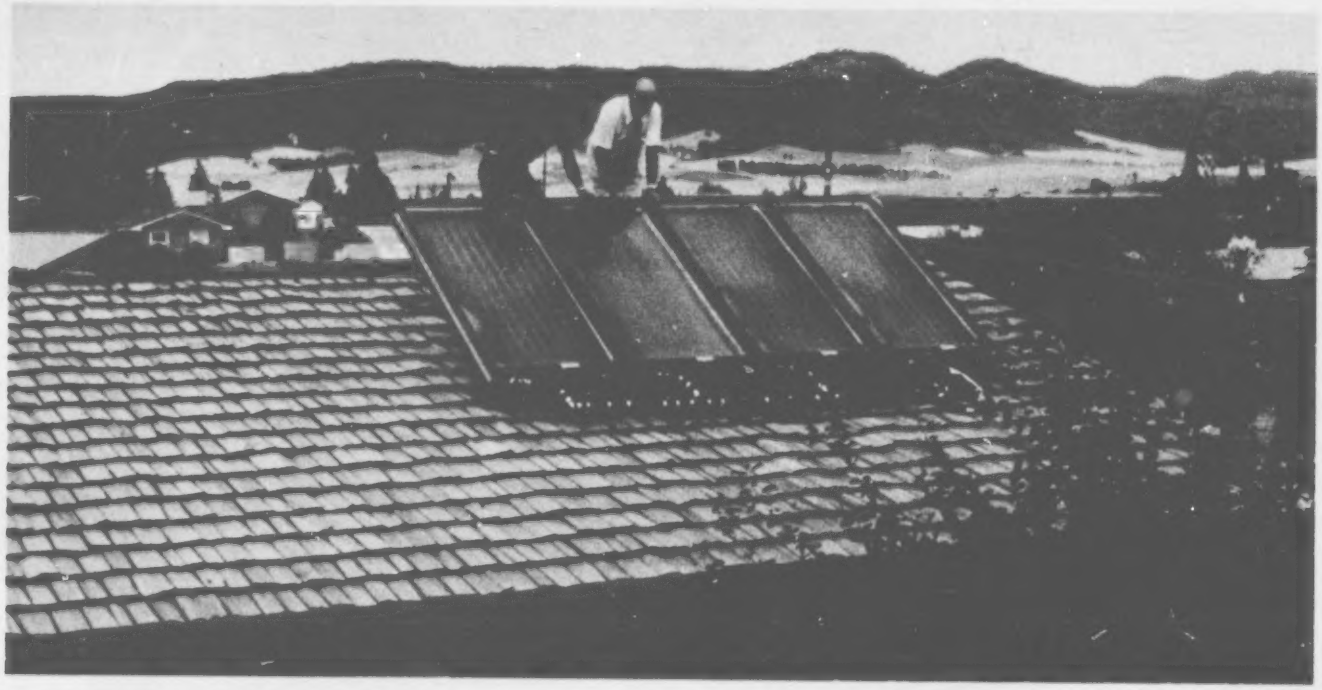
Used as a wall covering, the aluminized material offers extra insulation, reflects light and resists cracking. In addition to General Tire, King-Seeley also supplies wall covering material to Columbus Coated Fabrics Division of Borden, Incorporated, Columbus, Ohio, among others.



Solar Hot Water Heater The solar panels pictured below, mounted on a Moscow, Idaho home, are part of a domestic hot water heating system capable of providing up to 100 percent of home or small business hot water needs. Produced by Lennox Industries Inc., Marshalltown, Iowa, the panels are commercial versions of a collector co-developed by NASA.

In an effort to conserve energy, NASA has installed solar collectors at a number of its own facilities and is conducting research to develop the most efficient systems. Lewis Research Center teamed with Honeywell Inc., Minneapolis, Minnesota to develop the flat plate collector shown. Key to the collector's efficiency is a black chrome coating on the plate; developed for use on spacecraft solar cells, the coating prevents sun heat from "reradiating," or escaping outward. The design proved the most effective heat absorber among 23 different types of collectors evaluated in a Lewis test program.

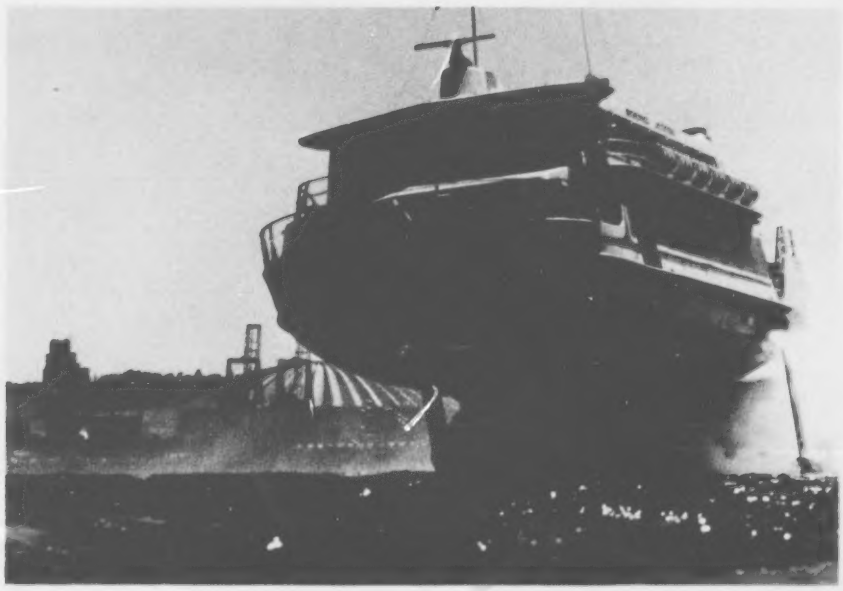
The Lennox solar domestic hot water heating system has three main components: the array of collectors, a "solar module" (blue unit pictured) and a conventional water heater. A fluid—ethylene glycol and water—is circulated through the collectors to absorb solar heat. The fluid is then piped to a double-walled jacket around a water tank within the solar module.



The jacket is a heat exchanger; the fluid circulates around the water tank and its heat is transferred to the water within. The working fluid, cooled in the process, is piped back to the collectors to repeat the cycle. As hot water is drawn from the conventional heater, sun-heated water from the solar module replaces it. When the sun is obscured by cloud cover, the conventional heater heats the water. In the Idaho installation shown, water heating bills were cut by two-thirds.

Highlighting spinoffs in the field of transportation is a technology transfer that helped improve the ride quality of a passenger-carrying hydrofoil

Smooth Passage For The Jetfoil



This photo of a Boeing Jetfoil shows how the hydrofoils lift the vessel's hull well above the surface, enabling the Jetfoil to cruise at 45 knots because of minimal friction between hull and water.

It is 260 nautical miles across the North Sea from Stavanger on Norway's west coast to Aberdeen in northern Scotland. That's a full day's travel for most conventional ships, a half day for the fastest. Last year a hydrofoil named the *Flying Princess* made a record-breaking crossing in just six hours 11 minutes, underlining the speed and convenience that is attracting more and more travelers to hydrofoil transportation.

The *Flying Princess* is a Boeing Jetfoil, one of a family of commercial waterjets built by Boeing Marine Systems, a division of The Boeing Company, Seattle, Washington. The new Jetfoil offers a number of advantages over earlier hydrofoils, a major one being a smooth ride in rough waters. NASA technology contributed to jolt-free passenger comfort.

Hydrofoils skim the surface at speeds considerably greater than those of conventional ships because there is little friction between hull and water. Hulls are raised above the water by the lift of the foils, which resemble and function like an airplane wing. The foils are attached to the hull by rigid struts, which ordinarily cause a vessel operating in coastal seas to follow the contour of the waves. In wind-whipped waters, this makes for a rough ride. Seeking to increase passenger acceptance, Boeing Marine System engineers looked for ways to improve rough-water ride quality.

Langley Research Center conducts continuing ride quality research. Initially, it was aimed at improving aircraft ride; it was later expanded to include all modes of transportation. Research includes studies of vibration, acceleration, temperature, humidity, passenger seats and posture, and the psychological aspects of passenger reaction to vehicle ride. As part of the program, Langley developed instrumentation, ride quality models and methods of data analysis. The University of Virginia, a Langley contractor, published a report on the subject and Langley held a Ride Quality Symposium.

A member of the Jetfoil development team attended the symposium and followed up by obtaining additional details of Langley's research. The NASA information led to Boeing's design of a computer-controlled system that automatically changes the pitch of the hydrofoils in response to changes in the water movement, eliminating much of the oscillation experienced by hydrofoils moving rapidly through rough water. The result, the company says, is rough-water ride quality unmatched by competitive craft.

Capable of cruising at 45 knots, the Jetfoil is powered by two waterjets, each driven by a gas turbine engine. The 90-foot, 110-ton, double-decked vessel is offered in various configurations, from a tourist version which

carries 190-250 passengers and their luggage, to a short-haul commuter version which can accommodate up to 400.

Water debris poses no problem for the Jetfoil, since its hydrofoil struts will shatter such obstacles as floating logs. In case the boat encounters something too solid to pierce—an extremely large log or a reef—the Jetfoil has a special design feature; the strut support system folds back, "giving" with the impact so that passengers experience something like the deceleration pressure of an airliner's thrust reversal after landing.

The Jetfoil made its operational debut in 1975, operating across the South China Sea from Hong Kong to Macao. In the same year it entered service in the Hawaiian Islands and last year additional services were initiated in Venezuela, Japan and across the English Channel from London to Zeebrugge, Belgium.

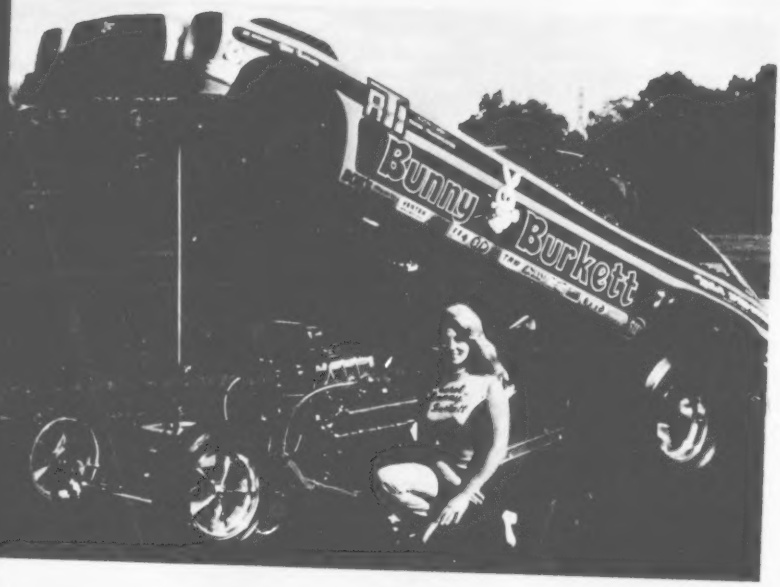
The hydrofoil Flying Princess, which last year made a record-breaking run across the North Sea from Norway to Scotland in six hours and 11 minutes. The 190-passenger vessel is now in commercial service, linking London and Zeebrugge, Belgium.

Mobile Phone Terminal In the photo, an employee of a real estate firm is contacting his office by means of HICOM, an advanced central terminal for mobile telephones. Developed by the Orlando Division of Martin Marietta Aerospace, Orlando, Florida, and manufactured by Harris Corporation's RF Division, Rochester, N.Y., HICOM upgrades service to users, provides better system management to telephone companies, and makes more efficient use of available mobile telephone channels through a computerized central control terminal.

The real estate man, for example, was able to dial his office and he could also have direct-dialed a long distance number. Mobile phones in most areas not yet served by HICOM require an operator's assistance for both local and long distance calls.

HICOM improves system management by automatically recording information on all calls for accurate billing, running continual performance checks on its own operation, and reporting any malfunctions to a central office. A particular advantage to the phone company is HICOM's ability to eliminate "call cheating." For years, mobile phone service companies have been plagued by "bandits." A bandit can purchase equipment on the open market and use the network without paying for the service, by giving the operator a fictitious number or a real number not his own. HICOM won't allow that. When a mobile phone is taken off its hook, the computer-controlled terminal immediately searches its memory to see if the caller is a legitimate subscriber. The user does not get a dial tone if he fails the computer test.

Development of HICOM was aided in part by NASA technology. Under contract to Marshall Space Flight Center, IBM Space Systems had prepared a report on improving computer reliability through "redundancy"—designing parallel modules so that if one failed the back-up would take over the function automatically. Martin Marietta-Orlando applied the NASA technology to the communications controller and realized substantial savings in development time and money.



Heat-resistant Paint The racing car shown is one of many coated with an inorganic paint that protects "hot parts" of automotive vehicles. Developed and manufactured by Sperex Corporation, Gardena, California, the durable, heat-resistant paint is used on car and truck exhaust systems, firewalls, brake drums and engine manifolds.

NASA technology contributed to development of the paint. Sperex was provided a technical support package detailing the research of Goddard Space Flight Center on long-life inorganic coatings. The information helped Sperex perfect its own formulations.

Oil-saving Seal Driven under difficult field conditions, the Army Jeep shown went more than 22,000 miles without an oil change in a test conducted by the U.S. Army Mobility Equipment Research and Development Command. Key to this exceptionally long oil life was a set of piston ring seals made of a new synthetic rubber formula called RC-34; the seal pictured, photographed *after* its arduous Army trial, shows no signs of deterioration. The seal and the RC-34 material, which may soon be available for use in the family auto, were developed by Ramsey Corporation, St. Louis, Missouri, a division of TRW Automotive Worldwide.

The oil in an automobile engine must be replaced every few thousand miles not because it wears out but because it becomes contaminated. The contamination sources are gasoline and combustion gases which blow by the piston rings to mix with the oil, reducing the oil's ability to lubricate properly. Seeking to prolong oil life by eliminating "blowby," Ramsey Corporation looked for a better way to seal piston rings and used NASA technology as a departure point. The parent company TRW, under contract to NASA's Jet Propulsion Laboratory, had developed seals and bladders from a type of material called elastomers which where designed to withstand the environmental extremes of interplanetary flight. That effort formed a knowledge base for research which culminated in Ramsey's RC-34 elastomer.

The RC-34 ring functions as a sealing gasket between the metal piston ring and the piston. The synthetic rubber ring is designed so that gas pressure increases the sealing effect. As the outer metal piston ring wears under long use, the RC-34 seal expands to fill wear gaps and therefore maintains a tight seal to prevent blowby. Still improving the design, Ramsey Corporation hopes to achieve automotive oil life of 30,000 miles or more. That would save about five of every six quarts of oil put into an auto engine during its lifetime, an extraordinary benefit to the family budget and to national energy conservation.

An unusual application to animal farming leads a sampling of food and agriculture spinoffs

Technology And Pregnant Pigs

One of the interesting things about aerospace spinoff is the way it keeps cropping up in uncommon applications unimaginably remote from the original technology.

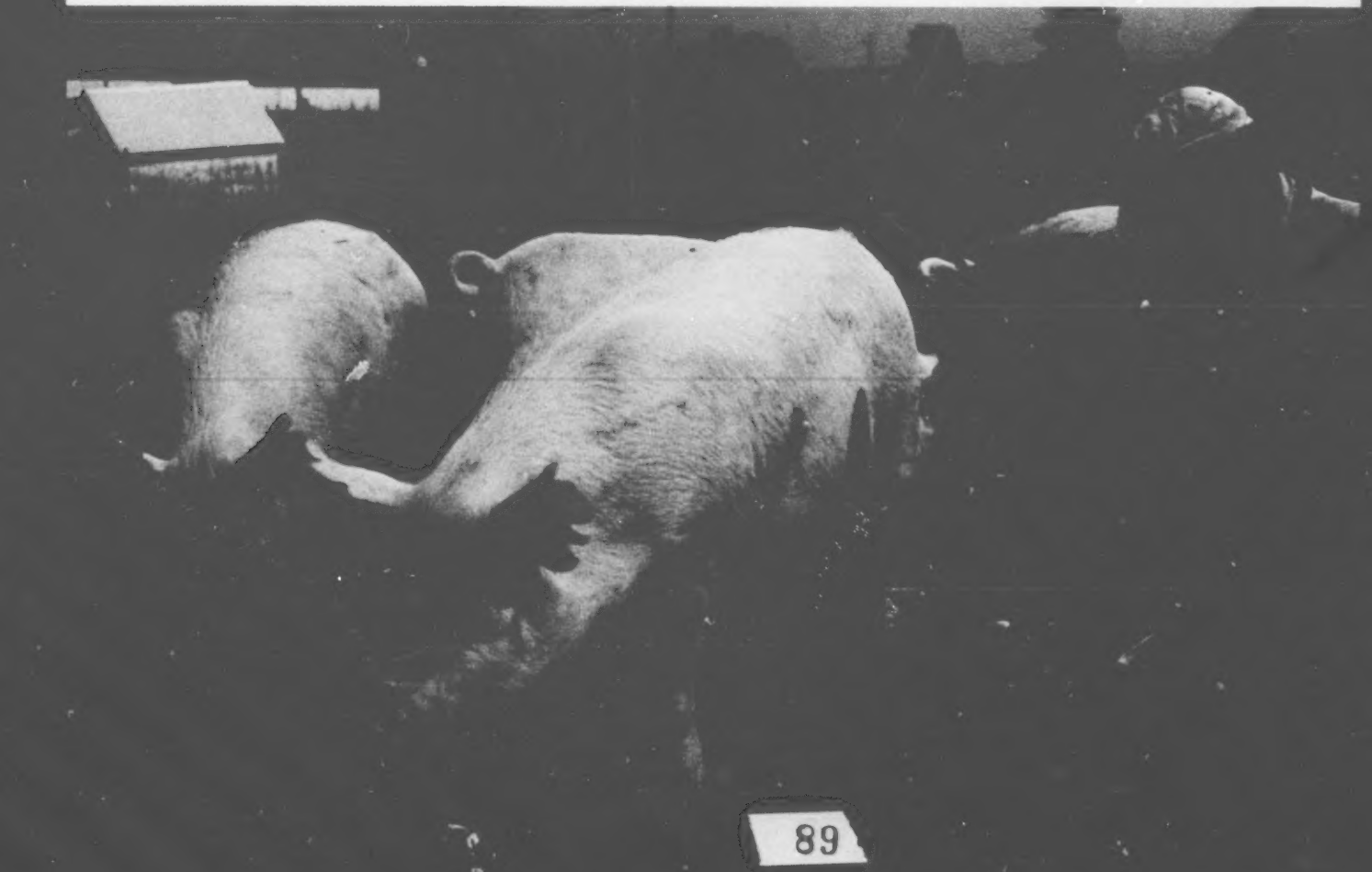
For example, the pig pregnancy detector.

The pig pregnancy detector? City folk may be surprised to learn that there is such a thing—and wonder why. The *why* is because it is a sow's job to produce piglets and farmers can't afford to keep those who don't; it costs about a half-dollar a day in feed, labor and facilities, and even in small herds that's intolerable. So the barren sow must go.

Until recently, the best method of determining pig pregnancy was "eyeballing," daily visual examination over a period of time. The problem with eyeballing is that pregnancy is not evident until well advanced; when there is no pregnancy, the farmer learns too late that he has been feeding a sow that won't give him a litter. Advancing technology provided an answer: the quick, easy-to-use, accurate automatic detector for *early* evaluation of pregnancy status.

Among the most popular of these devices are Scanopreg* and Scanoprobe*, to whose development NASA technology contributed. Scanopreg is an ultrasonic system which detects pregnancy about 30 days after breeding, long before eyeballing can provide an

*Registered trademark, Ithaco, Inc.



answer. The companion Scanoprobe is a dual-function unit which not only determines pregnancy but also gives farmers an analysis of a hog's meat-fat ratio, an important factor in breeding. Only a short time on the market, Scanopreg and Scanoprobe have already found wide acceptance among meat producers because they rapidly repay their cost.

Developed and manufactured by Ithaco, Inc., Ithaca, New York, Scanopreg and Scanoprobe are adaptations of technical expertise acquired by the company in years of work as a space equipment contractor. Ithaco specializes in spacecraft attitude control systems and the firm has been a participant in 20 different NASA satellite programs.

Scanopreg and Scanoprobe are portable, battery-powered devices that provide instant, simply-read information that meat producers need for profitable and efficient herd management. Each consists of an ultrasonic transmitter, a receiver, a mini-computer which processes information about the animal's innards, and a lighted display of the desired information.

For pregnancy testing, using either Scanopreg or Scanoprobe, the farmer places the instrument's cable-connected probe on the animal's lower flank. The transmitter sends harmless ultrasonic waves into the animal's body and "listens" for echoes. Echoes occur where there are changes in body density, so the receiver picks up reflected sound from the fluid surrounding fetuses in a pregnant animal. The processor interprets the echoes and the pregnant-or-not verdict appears on the screen in a matter of seconds.

Scanoprobe handles the additional assignment of determining the leanness of the meat the animal will produce. For this test, the probe is placed on a hog's back near the spine. The ultrasonic waves penetrate the multiple layers of fat and muscle and the type of echo returned permits the processor to compute the depth of each layer, or the ratio of fat to muscle.

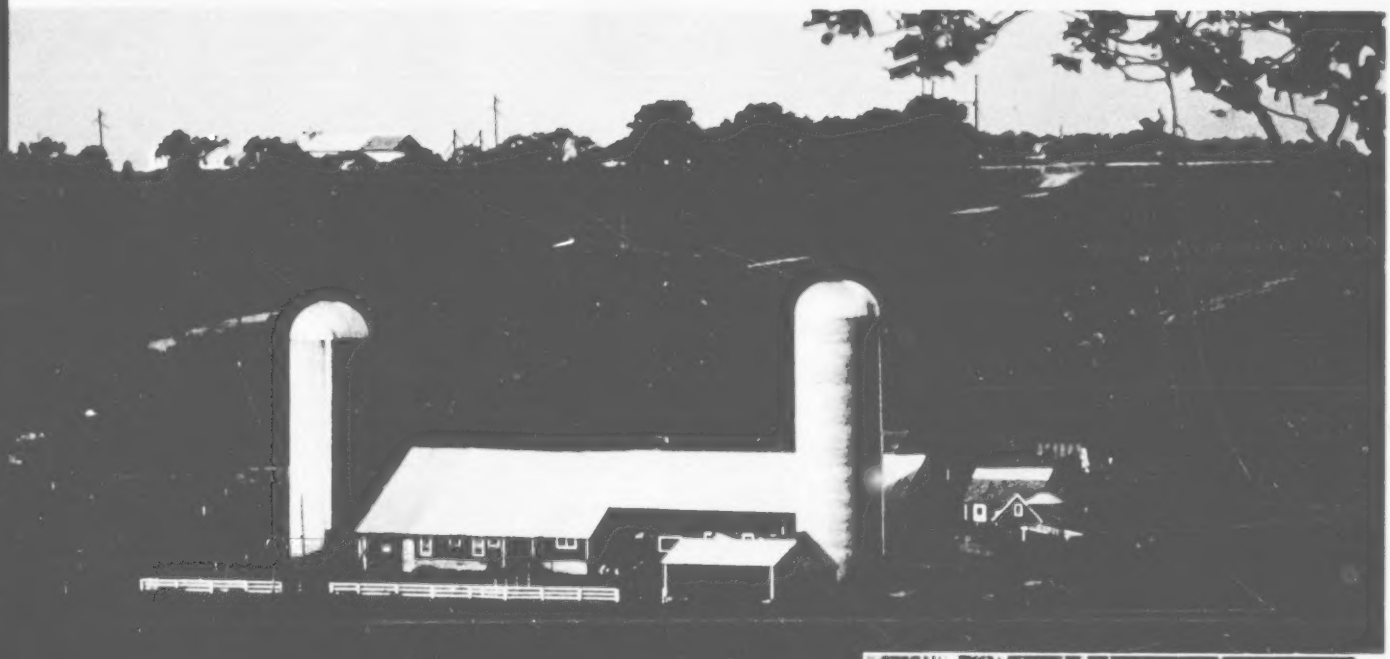
The farmer is using Scanopreg, an ultrasonic device which determines whether the sow will produce a litter. It saves money by permitting farmers to cull nonproductive animals out of the herd.

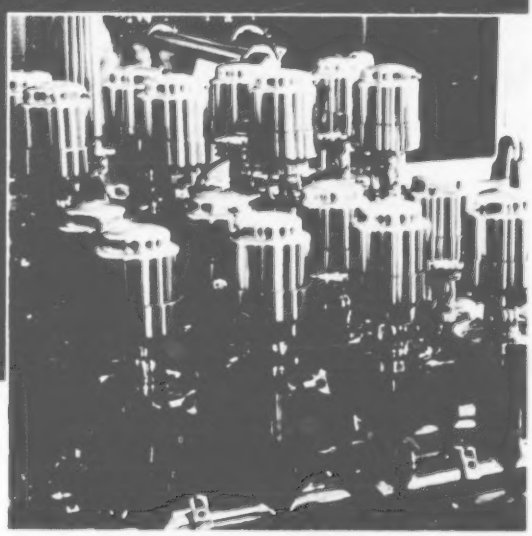
This type of measurement is economically important. Packing houses want lean meat and they pay premium prices for it. It has been established that the fat-to-meat ratio is a matter of heredity. Scanoprobe findings, therefore, contribute to herd productivity and profitability by enabling selection of the best boars and sows for breeding.

Used primarily by hog farmers, Scanopreg and Scanoprobe are also applicable to other animals for either pregnancy testing or fat-muscle measurement. They have, for example, found a market among New Zealand sheepherders. The devices have proved popular with foreign as well as American farmers and overseas purchases account for up to 40 percent of Ithaco's animal evaluation equipment sales.

This Scanopreg operator is applying corn oil to the unit's transducer to insure good contact between skin and probe. He will get an audible tone and a green light on the display if the animal is pregnant. If the sow is "open" —not pregnant—the red light will come on.

Companion unit to Scanopreg is Scanoprobe, which is also used as a pregnancy tester but has the additional capability of providing information on meat leanness, important in selecting animals for breeding.

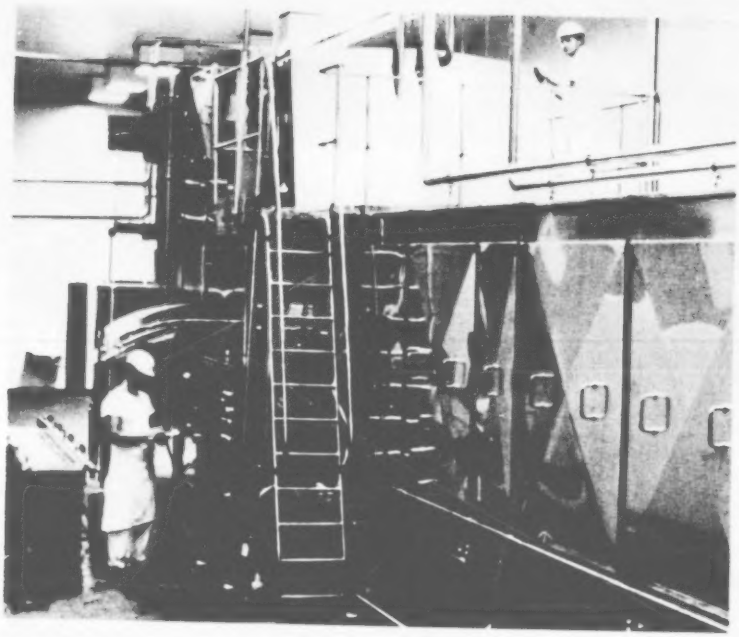




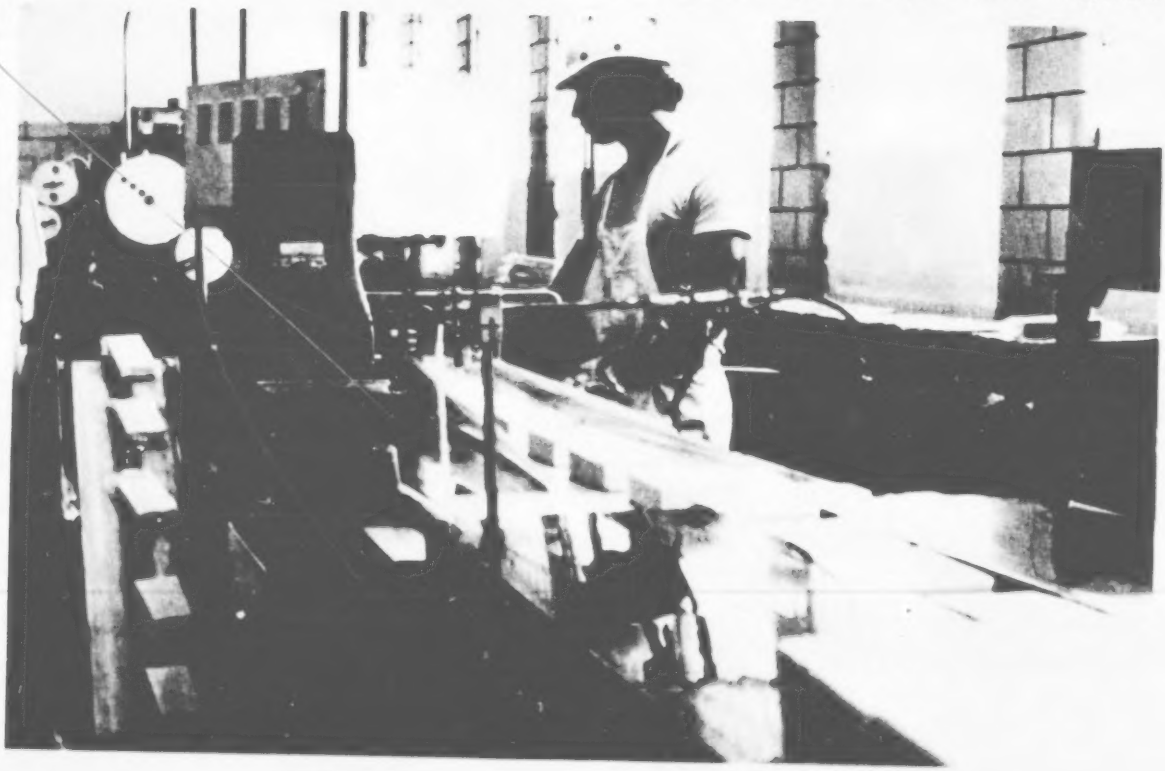
Dairy Equipment Lubrication Lake To Lake Dairy Cooperative, Manitowoc, Wisconsin, operates four plants in Wisconsin for processing milk, butter and cheese products from its 1,300 member farms. The large co-op was able to realize substantial savings by using NASA information for improved efficiency in plant maintenance.

Under contract to Marshall Space Flight Center, Midwest Research Institute compiled a handbook consolidating information about commercially available lubricants. The handbook details chemical and physical properties, applications, specifications, test procedures and test data for liquid and solid lubricants.

Lake To Lake's plant engineer used the handbook to effect savings in maintenance labor and materials costs by reducing the number of lubricants used on certain equipment. Strict U.S. Department of Agriculture and Food and Drug Administration regulations preclude lubrication changes in production equipment, but the co-op's maintenance chief was able to eliminate seven types of lubricants for ancillary equipment, such as compressors and high pressure pumps. Handbook data enabled him to select comparable but less expensive lubricants in the materials consolidation process, and simplified lubrication schedules and procedures. The handbook is in continuing use as a reference source when a new item of equipment is purchased.



The photo selection shows representative member farms and some of the ancillary and production equipment employed at the four plants, which are located in Manitowoc, Sheboygan, Kiel and Denmark, Wisconsin.



Food Packaging Material The photos show a few of the food products packaged in Alure, a metallized plastic material developed and manufactured by St. Regis Paper Company's Flexible Packaging Division, Dallas, Texas. The material incorporates a metallized film originally developed for space applications.

Among the suppliers of the film to St. Regis is King-Seeley Thermos Company, Winchester, Massachusetts. Initially used by NASA as a signal-bouncing reflective coating for the Echo 1 communications satellite, the film was developed by a company later absorbed by King-Seeley. The metallized film was also used as insulating material for components of a number of other spacecraft.

St. Regis developed Alure to meet a multiple packaging material need: good eye appeal, product protection for long periods and the ability to be used successfully on a wide variety of food packaging equipment. When the cost of aluminum foil skyrocketed, packagers sought substitute metallized materials but experiments with a number of them uncovered problems; some were too expensive, some did not adequately protect the product, some were difficult for the machinery to handle. Alure offers a solution.

St. Regis created Alure by sandwiching the metallized film between layers of plastics. The resulting laminated metallized material has the superior eye appeal of foil but is less expensive and more easily machined.

Alure effectively blocks out light, moisture and oxygen and therefore gives the packaged food long shelf life. A major packaging firm conducted its own tests of the material and confirmed the advantages of machinability and shelf life, adding that it runs faster on machines than materials used in the past and it decreases product waste; the net effect is increased productivity.

Easy Meal The woman pictured below is sitting down to a nutritious, easily-prepared meal similar to those consumed by Apollo astronauts. The appetizing dishes shown were created simply by adding water to the contents of a Mountain House* Easy Meal package of freeze dried food.

The Easy Meal line is produced by Oregon Freeze Dry Foods, Inc., Albany, Oregon, a pioneer in freeze drying technology and a company long associated with NASA in developing suitable preparations for use on manned spacecraft. Designed to provide nutritionally balanced, attractive hot meals for senior adults, Easy Meal is an offshoot of a 1975-77 demonstration project managed by Johnson Space Center and called Meal System for the Elderly. The project sought ways to help the estimated 3.5 million elderly Americans who are unable to take advantage of existing meal programs. Such services are provided by federal, state and local agencies, but they are not available to many who live in rural areas, or others who are handicapped, temporarily ill or homebound for other reasons.

Oregon Freeze Dry Foods was a participant in that multi-agency cooperative project. With its Easy Meal assortment of convenience foods pictured above left, the company is making commercially available meal packages similar to those distributed in the Meal System for the Elderly program.

In the freeze drying process, water is extracted from freshly-cooked foods by dehydration at very low temperatures, as low as 50 degrees below zero. Flavor is locked in by packaging the dried food in pouches which block out moisture and oxygen, the principal causes of food deterioration; thus the food can be stored for long periods without refrigeration. Meals are reconstituted by adding hot or cold water, depending on the type of food, and they are table ready in five to 10 minutes. Oregon Freeze Dry Foods offers five different meal packages and plans to expand the line.

*Registered trademark, Oregon Freeze Dry Foods, Inc.

A unique method of improving readability of old documents highlights examples of technology transfer in the fields of computer processing and communications systems

Making The Invisible Visible

Some 600 years ago, a Catalan physician named Arnald of Villanova wrote a treatise on surgical techniques of his day. Called *Speculum Medicine*, the work is invaluable to historians and medical researchers. Although much of the manuscript is well preserved, the toll of time has reduced parts of the text to faint, virtually invisible markings. But illegible portions, even sections that were once erased, have been made readable by a NASA image enhancement process originally developed to improve pictures sent to Earth from distant space. NASA's Jet Propulsion Laboratory (JPL), working with the California Institute of Technology, is now conducting demonstrations of the technology's utility for recovering such lost information.

JPL-Caltech researchers study an original medieval document preparatory to image enhancement. At right is the vidicon camera used to photograph pages for computer processing.

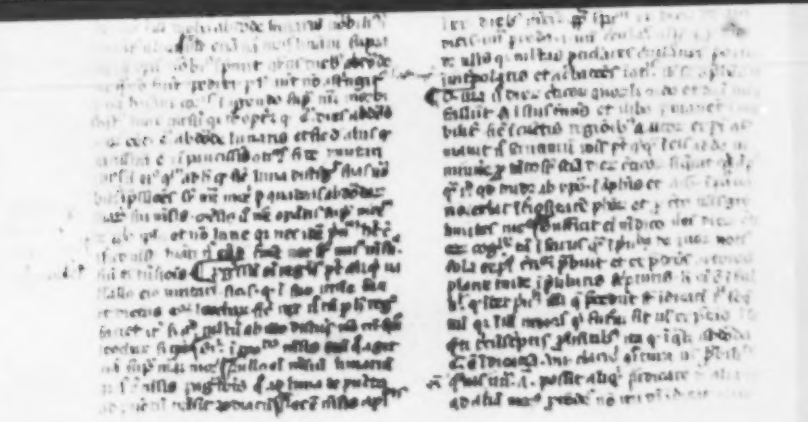
In public and private archives throughout the world there are many historically important documents that have become illegible with the passage of time. They have faded, been erased, acquired mold, water and dirt stain, suffered blotting or lost readability in other ways. While ultraviolet and infrared photography are widely used to enhance deteriorated legibility, these methods are more limited in their effectiveness than the space-derived image enhancement technique. The aim of the JPL effort with Caltech and others is to better define the requirements for a system to restore illegible information for study at a low page-cost with simple operating procedures.

The investigators' principal tools are a vidicon camera and an image processing computer program, the same equipment used to produce sharp space pictures. The camera is the same type as those on NASA's Mariner spacecraft which returned to Earth thousands of images of Mars, Venus and Mercury.

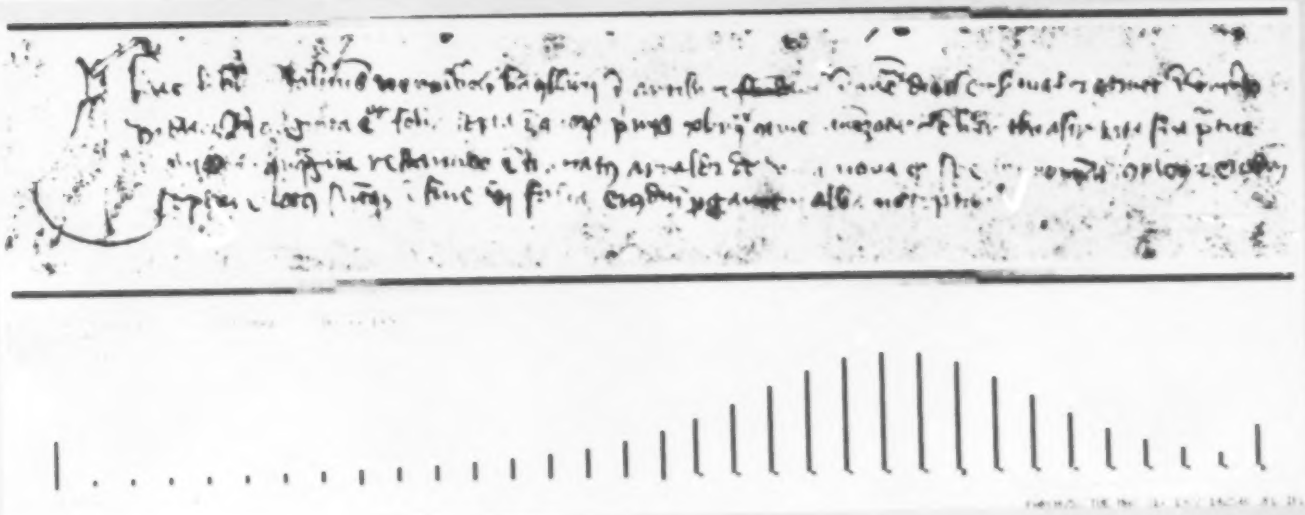
Space imagery works something like television. The vidicon camera does not take a photograph in the ordinary sense; rather it "scans" a scene, recording different light and shade values which are reproduced as a pattern of dots, hundreds of dots to a line, hundreds of lines in the total picture. The dots are transmitted to an Earth receiver, where they are assembled line by line to form a picture like that on the home TV screen.

But where television pictures are transmitted over relatively short distances, Mariner's images were relayed over tens of millions of miles, weakening in transit. That's where computer enhancement comes in; computer processing in effect amplifies the dots and lines, sharpening the image and revealing detail not originally visible.

In the document enhancing process, the vidicon camera scans a page and measures the brightness of hundreds of points along each line. The degree of brightness for each point is recorded on magnetic tape in digitized form, on a scale from zero for jet black to 255 for whitest white. The tape is then fed to the computer, which



The photo at left shows a page of a 14th century medical treatise with once-erased, almost invisible marginal notes along the bottom. Below is an image-enhanced reproduction of the invisible lines.

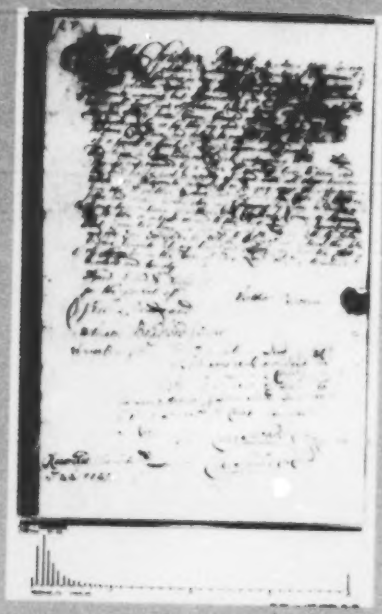


filters the data to remove background shading and sharpens the contrast to make otherwise invisible markings visible to the naked eye. The result is then played back and the reconstructed image is printed out.

This technique affords legibility superior to that attainable by other methods. Ultraviolet and infrared systems enhance writing or printed matter, but they simultaneously enhance the background, diminishing contrast. The space-developed combination of filtering and "contrast-stretching" produces the sharpest contrast possible with today's equipment. It can be coupled with ultraviolet and infrared images or used with direct visual lighting.

Much of the JPL work with Caltech has focused on *Speculum Medicine*, loaned to the investigators by its private owner, a California physician. Information illegible for centuries has been retrieved; for example, the process restored marginal notes that had been erased long ago and were almost invisible on the original parchment. The researchers have scored similar successes for other public organizations with old documents, such as a fragment of Cicero's *Republic*, the will of President Zachary Taylor, and legal papers from the 18th and 19th centuries.

JPL is continuing its document enhancing work, seeking to further advance the technique and to simplify computer programming. It has demonstrated the efficacy of the technology for transfer, but present operational procedures are too costly for wide application. The goal, considered feasible, is to design an affordable, readily operable image processing system that can be used by museums and libraries, either with their own equipment or through a commercial firm providing document improvement services.



Known as "Mrs. Brally's document," this legal paper is more than 250 years old and the unenhanced original shows it; its smudges, blurs and varying contrast levels make it extremely difficult to read. The larger picture shows the same document, its legibility enormously improved after processing by Jet Propulsion Laboratory's computerized image enhancement technique.

Many museums and libraries have historically important documents whose contents have become illegible over a period of years. Skilled library technicians have methods and equipment for restoring lost information, but there is a need for a simple system that would enable scholars unskilled in document improvement to study illegible papers. Jet Propulsion Laboratory and Caltech are working toward design of such a system, an affordable, easy-to-operate image processor for general use.

Pipe Line Control The array of tanks, pipes and valves in the photo below is a petroleum tank farm in Georgia, part of a petrochemical pipe line system that moves refined petroleum products from Texas and Louisiana to the mid-Eastern seaboard.

The same pipes handle a number of different products, such as gasoline, kerosene, jet fuel or fuel oil. The fluids are temporarily stored in tanks, pumped into the pipes in turn and routed to other way stations along the pipe line. The complex job of controlling, measuring and monitoring fuel flow is accomplished automatically by a computerized control and communications system which incorporates multiple space technologies.

Developed by SCI Systems, Inc., Huntsville, Alabama, the pipe line's brain is known as the Remote Data Acquisition Control System II (RDACS II). A departure point for its development was SCI's Remote Automatic Calibration System, which provided measurements used to calibrate telemetry equipment in the Saturn launch vehicles that boosted NASA's Apollo spacecraft. Digital data transfer techniques developed by SCI for NASA's Space Shuttle are also incorporated in RDACS II, as is space-derived "redundancy management"—automatic takeover by a backup system when a primary unit malfunctions.

The RDACS II shown in the small photo is one of six located at hub control centers along the pipe line. A seventh at Atlanta, Georgia —called the "granddaddy"—oversees the operation of the other six. Collectively, the RDACS control the entire fuel-movement function: turning valves to feed fuel from tanks into the line, checking to make sure that the proper valves are open or closed, measuring fuel flow, assuring maximum efficiency of the pumping equipment, and generally monitoring the progress of the fluids in the pipe line to make sure that the right amount of the right fuel gets to the proper destination.

Laserfax The photo shows an Associated Press technician receiving a photograph prepared by means of a high speed, high resolution facsimile system known as Laserfax, so called because it employs a laser beam to scan the photo being sent. Laser scanning data is converted to electrical signals and transmitted to news bureaus within the Associated Press network via microwave radio or telephone lines. At the other end, another laser sweeps reconverted imagery onto a special, light-sensitive, dry silver paper. The paper is then heat processed to reproduce the photograph.

Manufactured by Harris Electronics Systems Inc., Melbourne, Florida, Laserfax incorporates NASA thermal control coating technology developed by Jet Propulsion Laboratory for use on spacecraft antennas; the coatings block absorption of solar radiation which would interfere with the antenna's proper operation.

Harris Electronics Systems, originally Radiation, Inc., reused the NASA technology in development of Laserfax. A NASA technical support package provided information about the thermal properties that could be expected of various coatings for the facsimile system's paper rollers; this information served as a design base for the infrared heat source used in developing the photo.

Although relatively new, Laserfax is in extensive service. It is manufactured in several models. One of them is the type used by the Associated Press, its news bureaus and affiliated newspapers, radio and television stations. Other models have been sold in large numbers to law enforcement agencies for transmitting high quality fingerprints and identification photos. Laserfax is also in service with the National Weather Service, which converts satellite imagery to weather photographs and relays them to local weather stations, television stations, newspapers and airlines.

Bank Terminals In the photo, employees of the UAB Bank, Knoxville, Tennessee, are using Teller Transaction Terminals manufactured by SCI Systems, Inc., Huntsville, Alabama, an electronics firm which has worked on a number of space projects under contract with NASA. The terminals are part of an advanced, computerized financial transaction system that offers high efficiency in bank operations.

The key to the system's efficiency is a "multiplexing" technique developed for NASA's Space Shuttle. Multiplexing is simultaneous transmission of large amounts of data over a single transmission link at very high rates of speed. In the banking application, a small multiplex "data bus" interconnects all the terminals and a central computer which stores information on clients' accounts. The data bus replaces the maze of wiring that would be needed to connect each terminal separately and it affords greater speed in recording transactions.

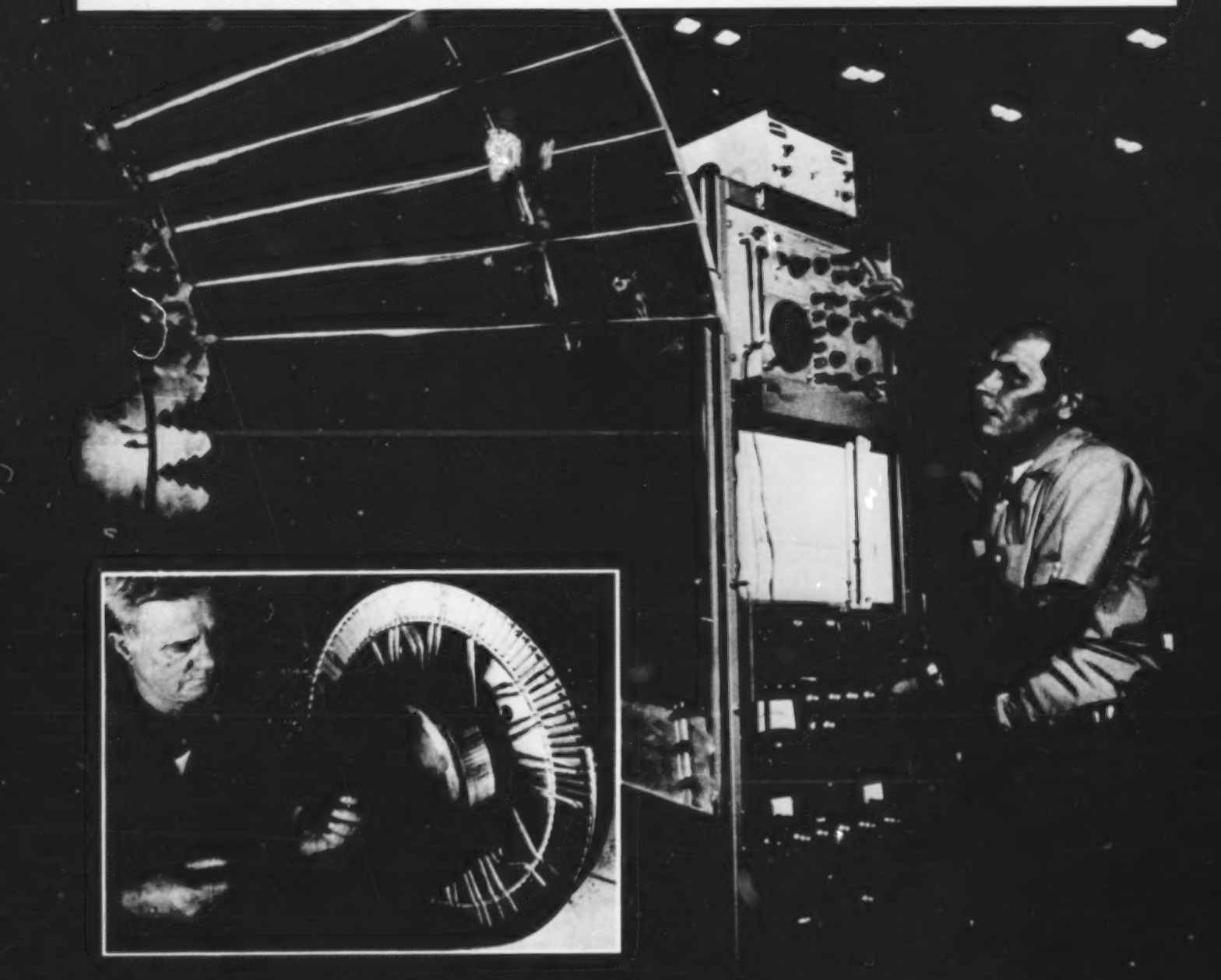
The SCI system offers banks real-time data management through constant updating of the central computer. For example, a check is immediately cancelled at the teller's terminal and the computer is simultaneously advised of the transaction; under other methods, the check would be cancelled and the transaction recorded at the close of business. Teller checkout at the end of the day, conventionally a time-consuming matter of processing paper, can be accomplished in minutes by calling up a summary of the day's transactions.

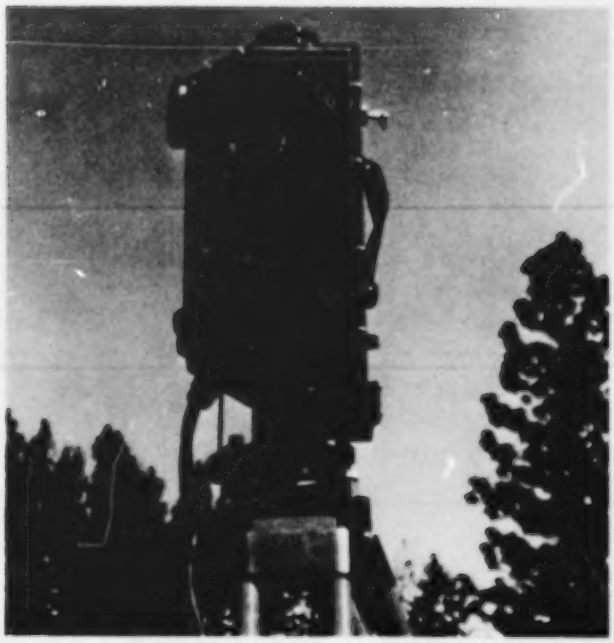
SCI manufactures other types of terminals for use in the system, such as an administrative terminal that provides an immediate printout of a client's account, and another for printing and recording savings account deposits and withdrawals. SCI systems have been installed in several banks in Tennessee, Arizona, and Oregon and additional installations are scheduled this year.

Computer Programs NASA computer programs are extensively used in design of industrial equipment. Available from the Computer Software Management and Information Center (COSMIC) at the University of Georgia, these programs are employed as analysis tools in design, test and development processes, providing savings in time and money.

For example, two NASA computer programs are used daily in the design of turbomachinery by Delaval Turbine Division, Trenton, New Jersey. The company uses the NASA splint interpolation routine for analysis of turbine blade vibration and the performance of compressors and condensers. A second program, the NASA print plot routine, analyzes turbine rotor response and produces graphs for project reports.

The photos show examples of Delaval test operations in which the computer programs play a part. In the large photo below, a 24-inch turbine blade is undergoing test; in the smaller photo, a steam turbine rotor is being prepared for stress measurements under actual operating conditions; the "spaghetti" is wiring for test instrumentation.

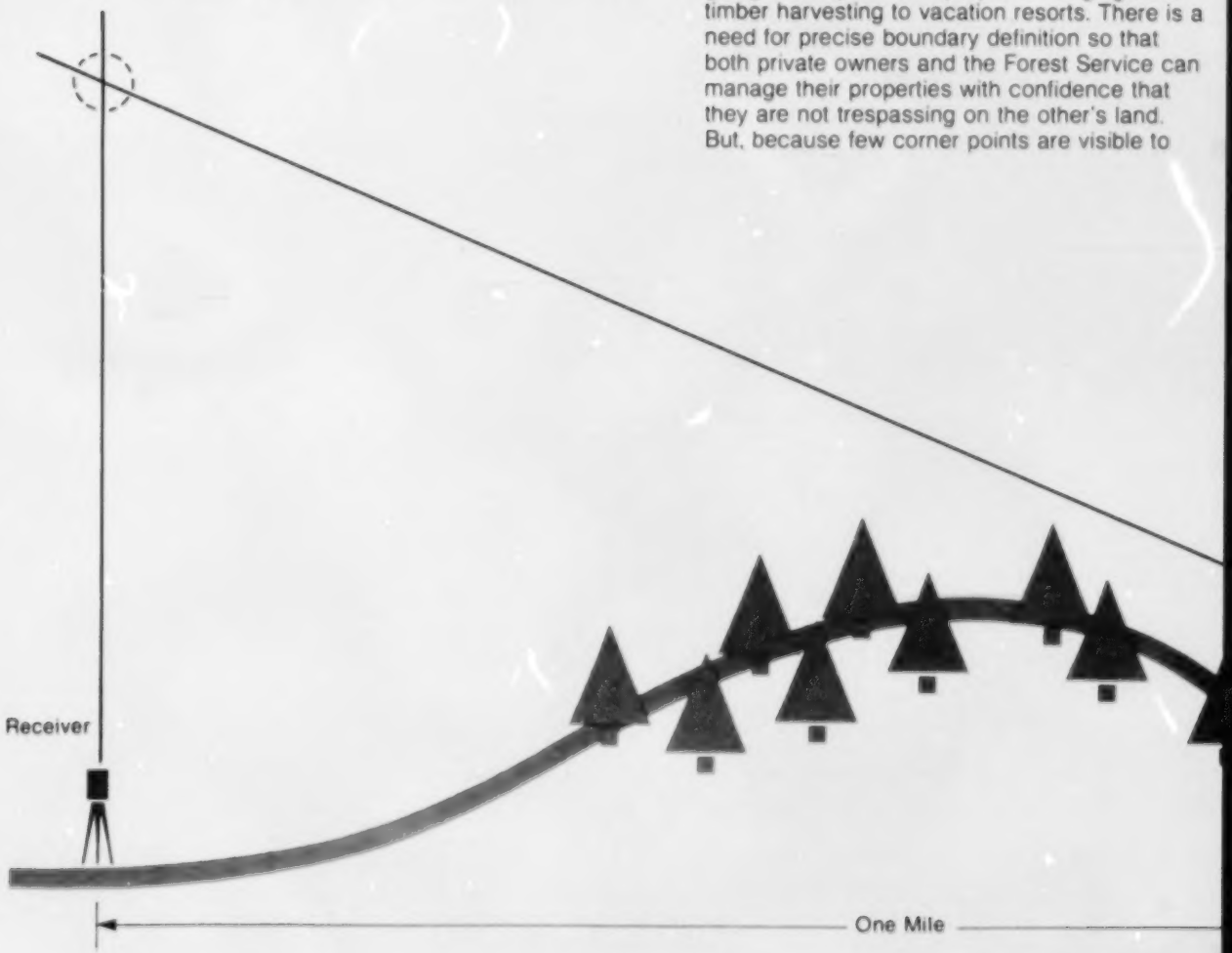




Laser Surveying NASA technology has produced a laser-aided system for surveying land boundaries in difficult terrain. It does the job more accurately than conventional methods, takes only one-third the time normally required, and is considerably less expensive.

In surveying to mark property boundaries, the objective is to establish an accurate heading between two "corner" points. This is conventionally accomplished by erecting a "range pole" at one point and sighting it from the other point through an instrument called a theodolite. But how do you take a heading between two points which are not visible to each other, for instance, when tall trees, hills or other obstacles obstruct the line of sight? That was the problem confronting the U.S. Department of Agriculture's Forest Service.

The Forest Service manages 187 million acres of land in 44 states and Puerto Rico. Unfortunately, National Forest System lands are not contiguous but intermingled in complex patterns with privately-owned land. In recent years much of the private land has been undergoing development for purposes ranging from timber harvesting to vacation resorts. There is a need for precise boundary definition so that both private owners and the Forest Service can manage their properties with confidence that they are not trespassing on the other's land. But, because few corner points are visible to

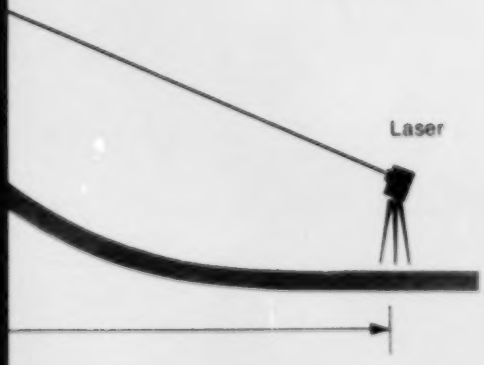


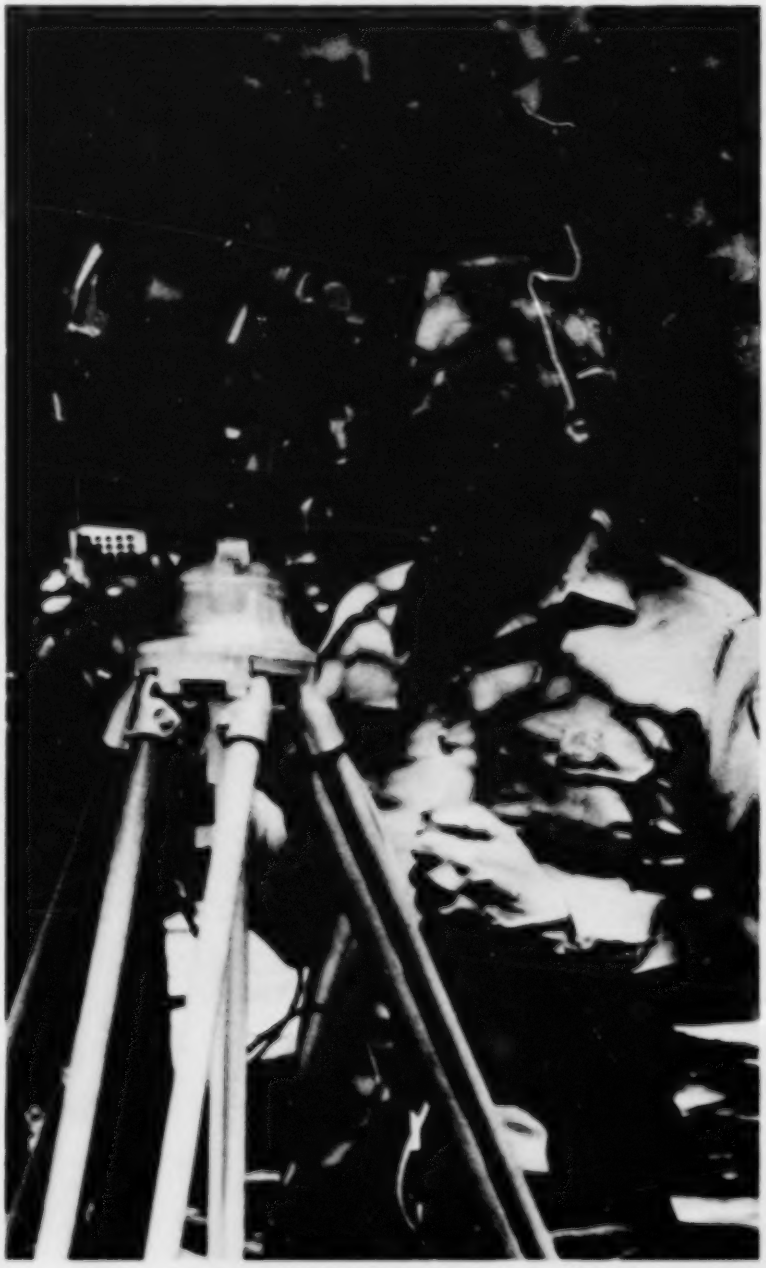
each other, the surveying task posed monumental problems and the Forest Service was faced with a rapidly growing backlog of unposted boundary lines.

The Forest Service considered ways of sighting over obstructions. The practical limit for extending the height of the range pole was six or eight feet. Tethering a balloon over a corner marker was feasible, but wind effect makes the balloon an inaccurate aiming point. Building towers is too costly and time consuming. Use of helicopters is also very expensive and not sufficiently accurate. So the Forest Service took the problem to NASA's Goddard Space Flight Center. Goddard undertook the assignment and came up with an answer: a laser system, diagrammed in the drawing below, which enables sighting between two points not intervisible with accuracy greater than conventional techniques.

The system, commercially produced by RCA's Automated Systems Division, Burlington, Massachusetts, is called the "laser range pole." It consists of two elements, a laser transmitter and a receiver/theodolite, which weigh a combined 58 pounds and can be backpacked into rugged country. The tripod-mounted transmitter pictured on the opposite page sends a vertical column of light straight upward from a corner marker. Although the laser beam is invisible to the human eye, it can be picked up by electronic eyes in the receiver/theodolite, stationed at another corner marker a mile or more away. The theodolite operator (right photo) makes fine adjustments to his sighting equipment until an indicator light tells him his optical sight is correctly aligned with the laser beam. This establishes a precise heading between the two boundary markers, allowing crews to set stakes along the heading by conventional line of sight methods.

The Forest Service is using three laser range poles, two of them improved, second-generation systems which far exceed the original range specification of one mile; they are effective over distances of two and a half miles in daytime and five miles at night. The Department of the Interior's Bureau of Land Management has purchased four of the improved laser devices from RCA, to be used principally for surveying oil-shale land boundaries. The system has a number of surveying applications beyond boundary marking. Goddard Space Flight Center, under contract with the Department of Agriculture, is redesigning the equipment to make it less expensive for broader use.





A solar energy project in a model town exemplifies a special area of NASA effort—service to communities through demonstrations of advantageous technology

A New Look For Greenbelt

The solar panels on the roof of this multi-unit building at Greenbelt, Maryland provide almost half of the heating and domestic hot water needs of the four resident families. The solar system was designed by NASA's Goddard Space Flight Center as a community aid project.

Greenbelt, Maryland, 12 miles from the nation's capital, is an efficiently planned model town and most of its 1600 homes are almost identical in appearance. Four of them, however, stand out from their neighbors; they have distinctive blue glass rooftop superstructures made up of a series of solar collectors. They are part of a NASA community aid program, a joint energy research project involving the Greenbelt housing cooperative and NASA's Goddard Space Flight Center, located near the community.

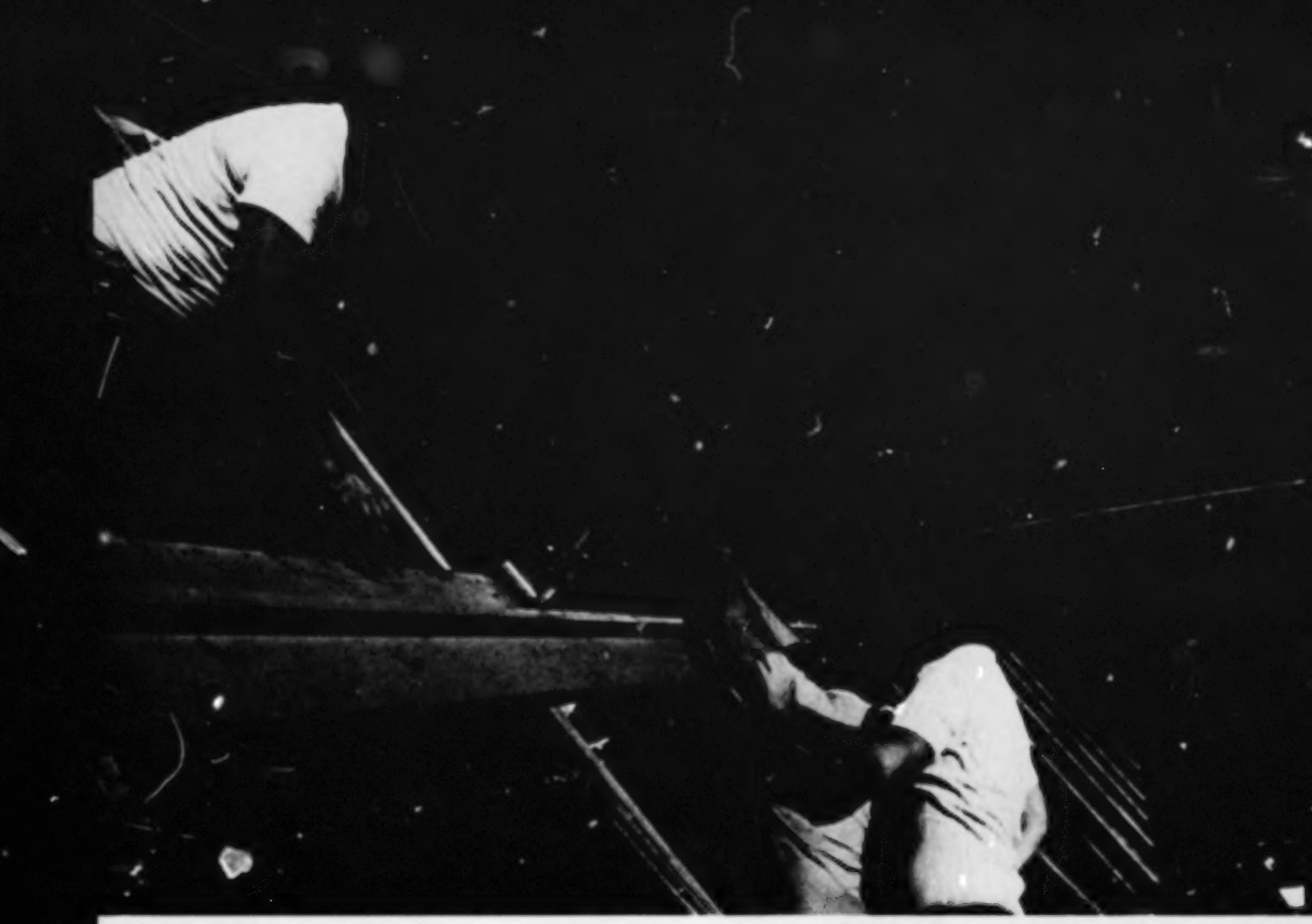
Built in 1935, Greenbelt is one of three government-planned communities of President Franklin D. Roosevelt's first administration; the others are Greendale, Wisconsin and Greenhills, Ohio. The government built the towns to make available low-cost housing, provide employment for workers on relief in the Great Depression era, and to establish models designed to encourage construction of similar developments by private industry. In 1952, the residents of Greenbelt formed a non-profit cooperative called Greenbelt Homes, Inc., which bought the dwellings, facilities and a large part of the land from the government. The homes are individually owned but collectively maintained by the co-op, with each owner paying a prorated share of utility and maintenance costs.

Greenbelt residents are mostly in the low and medium income brackets, and one of every three families lives on a fixed retirement income. For that reason, the sharp escalation of fuel oil prices that began in 1973 imposed particular hardship on the co-op community. So Greenbelt Homes' management asked its NASA neighbor, Goddard Space Flight Center, for assistance in setting up a solar energy research project. The idea was to conduct a small scale demonstration to show what savings could be realized by solar heating Greenbelt homes, with an eye toward possible future expansion of solar energy systems as a means of combating rising fuel costs.

Goddard undertook the project as part of the federal government's effort to research and demonstrate ways of conserving energy. The Center was well qualified for the assignment, having acquired extensive expertise in designing thermal control systems for satellites, which must maintain stable temperatures for successful operation.

Goddard selected for the experiment a flat-roofed building containing four separate homes heated by a common oil-fueled hot water heating system. Goddard designed the solar array, controls and instrumentation and procured commercially-available solar heating equipment; construction work was handled by Greenbelt Homes' maintenance crew.

The research structure was insulated and equipped with solar collectors mounted at pitched angles on the roof. Each collector is a glass-covered metal container housing a network of small water pipes. The pipes run to and from a large hot water storage tank



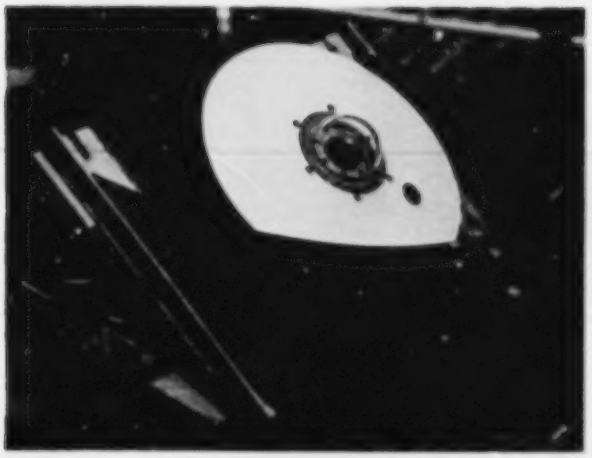
beneath the building. In operation, water is directed through the solar collectors, heated by the sun and routed back to the storage tank, from which it is pumped into the building's regular hot water heating system as needed. During periods when the sun is obscured by clouds, the existing oil furnace automatically takes over the heating job.

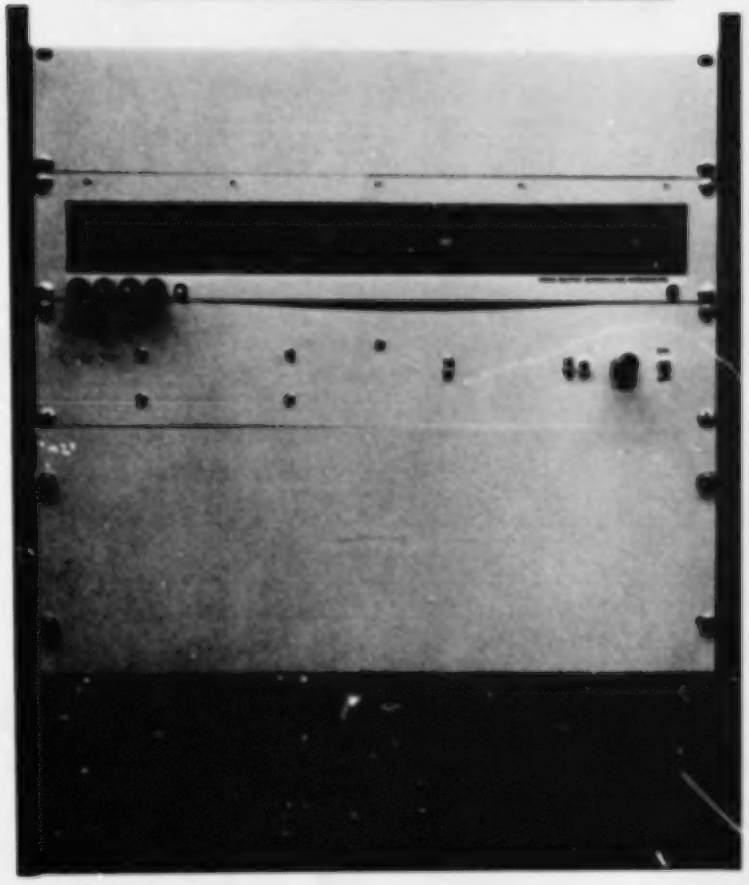
To study the system's effectiveness, Goddard instrumented the building to determine oil consumption, water usage and temperatures. For comparison purposes, one other Greenbelt structure without solar collectors was similarly instrumented.

Goddard engineers recorded information through two winter-summer cycles and are now analyzing the data. Preliminary estimates indicate that the solar collectors save between 40 and 50 percent of the oil needed to meet home heating and domestic hot water needs. Based on a mortgage interest rate of eight and one-half percent and a fuel price escalation of 10 percent per year, the fuel savings would repay the cost of installation in about 25 years. Should fuel costs escalate more rapidly or should systems installations become cheaper—both are likely considerations—the cost benefit of solar energy systems will increase and reduce the investment recovery time.

The Greenbelt project is an example of NASA's community services effort, in which NASA provides technological assistance to communities, state and local governments, medical institutions and other organizations. Generally, this work involves demonstrations of how the application of new technology can help solve major problems or produce better ways of meeting public needs. In this special area of technology utilization, some product spinoff may evolve from the technology applied, but product commercialization is not the primary aim; the intent is to pave the way for community-sponsored application of beneficial technology. The following pages contain other examples of NASA's participation in programs of this type.

Shown during installation, the solar panels encase a network of water pipes, visible in left foreground. Water pumped through the panels is heated by the sun, then stored in an insulated underground tank until needed for home heating or hot water.

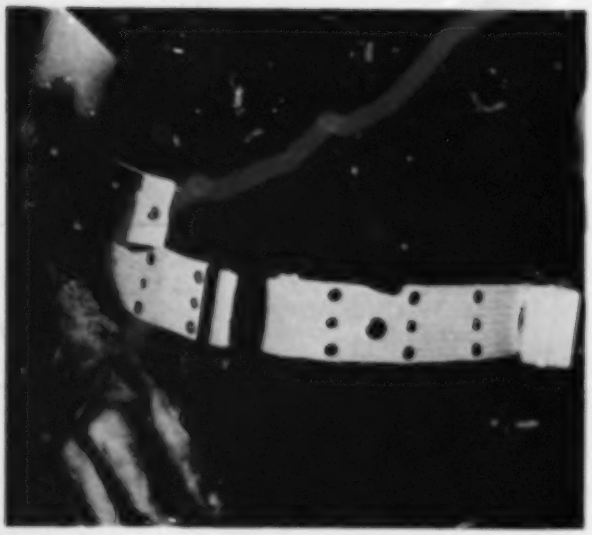




Solar Energy Reporting Last year the people of Cleveland, Ohio were troubled by natural gas shortages during one of the coldest winters on record. The severe winter generated a great deal of interest in solar energy as an alternative source of heat. Home owners, home builders and civic officials wanted to know just how much solar energy is available in Cleveland. Now they get a daily report through the city's news media, from information supplied as a community service by NASA's Lewis Research Center.

Lewis routinely makes daily measurements of solar energy as part of its continuing research in behalf of the Department of Energy. The measuring device is a sun sensor called a pyranometer (upper photo) located atop a building at the NASA Center. To make the information conveniently available to news media, Lewis developed a Voice Output Integrating Insolometer shown at right, an automated system that acquires information from the sun sensor and translates it into a recorded telephone message.

The Lewis pyranometer collects sun data for 15 hours daily and measures the total solar energy yield. For reporting to the public, the information is electronically converted to a specific reading. A media representative calling in gets a voice-synthesized announcement of a two or three digit number; the number corresponds to the kilowatt-hours of solar energy that would be available to a typical 500-square-foot solar collector system. Response in Cleveland has been favorable and interest is developing in other parts of the country.



Eye Surgery Light During eye surgery, the surgeon uses an illuminating instrument called an opthalmoscope for close examination of the retina or the interior of the eye. Ordinarily, electric power for the head-mounted light is supplied through a cord from an overhead swivel arm or a floor pedestal. Within limits of cord length and swivel arm movement, the surgeon has considerable freedom of motion. But when more than one opthalmoscope is involved, tangling and interference of the power cords becomes a problem.

St. Luke's Hospital, Cleveland, Ohio asked Lewis Research Center for assistance in finding a solution. Lewis responded with a battery-powered system that totally frees the surgeon of attached cords and swivels.

Borrowing from space technology, Lewis used small, lightweight nickel-cadmium batteries that can deliver high intensity light for an hour and can be recharged overnight. The Opthalmoscope Powerpack consists of eight batteries in three containers affixed to a webbed belt, and a novel on-off switch equipped with a spring-loaded plexiglass "flapper." The belt pack is worn underneath the surgical gown and the flapper permits the doctor to activate the switch by elbow pressure (upper photo).

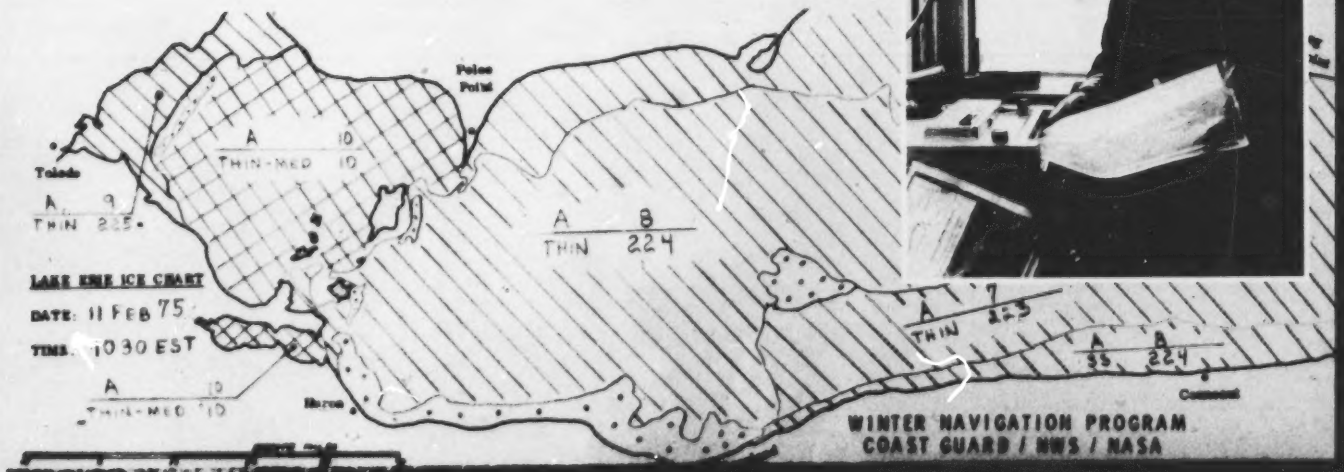
Lewis built five units and they have been in service at St. Luke's Hospital for a year. Used for routine examinations as well as for surgery, they have demonstrated excellent reliability.

Waterway Ice Thickness Measurements The ship on the opposite page is a U.S. Steel Corporation tanker cruising through the ice-covered waters of the Great Lakes in the dead of winter. The ship's crew is able to navigate safely by plotting courses through open water or thin ice, a technique made possible by a multi-agency technology demonstration program in which NASA is a leading participant.

Traditionally, the Great Lakes-St. Lawrence Seaway System is closed to shipping for more than three months of the winter season because of ice blockage, particularly fluctuations in the thickness and location of ice cover due to storms, wind, currents and variable temperatures.

Shippers have long sought a system of navigation that would allow year-round operation on the Lakes and produce enormous economic and fuel conservation benefits. Interrupted operations require that industrial firms stockpile materials to carry them through the impassable months, which is costly. Alternatively, they must haul cargos by more expensive overland transportation. Studies estimate the economic benefits of year-round Great Lakes shipping in the hundreds of millions of dollars annually and fuel consumption savings in the tens of millions of gallons.

Under Project Icewarn, NASA, the U.S. Coast Guard and the National Oceanic Atmospheric Administration collaborated in development and demonstration of a system that permits safe year-round operations. It employs airborne radars, satellite communications relay and facsimile transmission to provide shippers and ships' masters up-to-date ice charts. Lewis Research Center contributed an accurate method of measuring ice thickness by means of

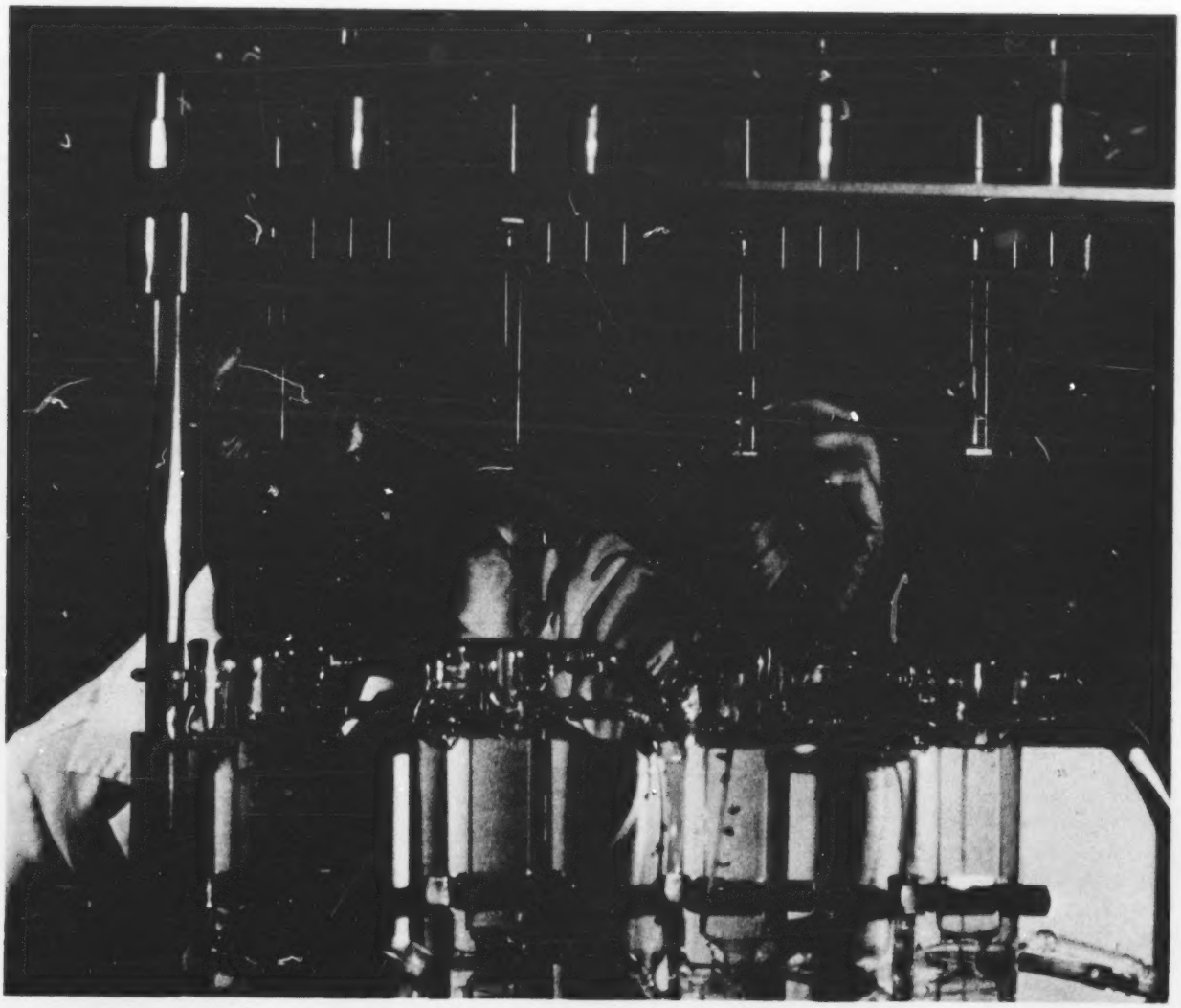


a special "short-pulse" type of radar.

In a three-year demonstration program, Coast Guard aircraft equipped with Side-Looking Airborne Radar (SLAR) flew over the Great Lakes three or four times a week. The SLAR, which can penetrate clouds, provided large area readings of the type and distribution of ice cover. The information was supplemented by short-pulse radar measurements of ice thickness. The radar data was relayed by a NOAA satellite to a ground station where NOAA analyzed it and created picture maps, such as the one shown at lower left, showing where icebreakers can cut paths easily or where shipping can move through thin ice without the aid of icebreakers. The ice charts were then relayed directly to the wheelhouses of ships operating on the Lakes.

Following up the success of the Great Lakes program, the Icewarn team applied its system in another demonstration, this one a similarly successful application designed to aid Arctic coast shipping along the Alaskan North Slope.

Further improvement of the ice-monitoring system is planned. Although aircraft-mounted radar is effective, satellites could provide more frequent data. After the launch this year of Seasat, an ocean-monitoring satellite, NASA will conduct tests to determine the ice-mapping capability and accuracy of satellite radar images.



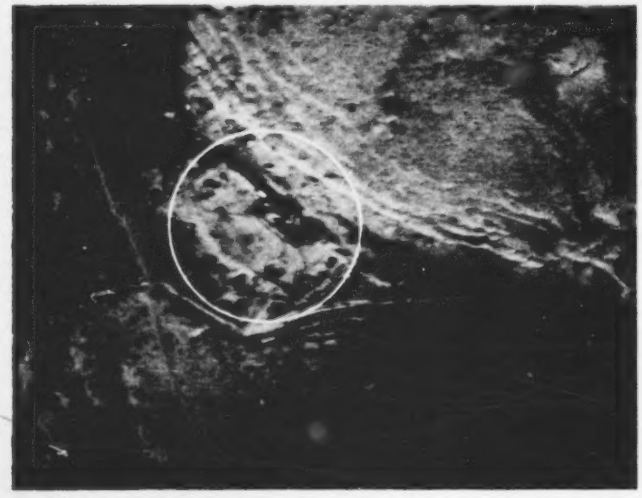
Blood Vessel Tension Tester In the photo, a medical researcher is using a specially-designed laboratory apparatus for measuring blood vessel tension. It was designed by Langley Research Center as a service to researchers of Norfolk General Hospital and Eastern Virginia Medical School, Norfolk, Virginia.

The investigators are studying how vascular smooth muscle—muscle in the walls of blood vessels—reacts to various stimulants, such as coffee, tea, alcohol or drugs. They sought help from Langley Research Center in devising a method of measuring the tension in blood vessel segments subjected to various stimuli. The task was complicated by the extremely small size of the specimens to be tested, blood vessel "loops" resembling small rubber bands, some only half a millimeter in diameter.

Langley's Instrumentation Development Section responded with a miniaturized system whose key components are a "micropositioner" for stretching a length of blood vessel and a strain gage for measuring the smooth muscle tension developed. The micropositioner is a two-pronged holder. The loop of blood vessel is hooked over the prongs and it is stretched by increasing the distance between the prongs in minute increments, fractions of a millimeter. At each increase, the tension developed is carefully measured. In some experiments, the holder and specimen are lowered into the test tubes shown, which contain a saline solution simulating body fluid; the effect of the compound on developed tension is then measured. The device has functioned well and the investigators say it has saved several months research time.

Archeological Surveys NASA remote sensing technology is being employed in archeological studies of the Anasazi Indians, who lived in New Mexico one thousand years ago. Under contract with the National Park Service, NASA's Technology Applications Center at the University of New Mexico is interpreting multispectral scanner data and demonstrating how aerospace scanning techniques can uncover features of prehistoric ruins not visible in conventional aerial photographs.

The Center's initial study focused on Chaco Canyon, a pre-Columbia Anasazi site in northeastern New Mexico. Chaco Canyon is a national monument and it has been well explored on the ground and by aerial photography. But the National Park Service was interested in the potential of multispectral scanning for producing evidence of prehistoric roads, field patterns and dwelling areas not discernible in aerial photographs. The multispectral scanner produces imaging data in the invisible as well as the visible portions of the spectrum. This data is converted to pictures which bring out features not visible to the naked eye or to cameras.



The Technology Applications Center joined forces with Bendix Aerospace Systems Division, Ann Arbor, Michigan, which provided a scanner-equipped airplane for mapping the Chaco Canyon area. The NASA group processed the scanner images and employed computerized image enhancement techniques to bring out additional detail.

The study concluded that multispectral analysis can be valuable to field archeologists in their searches for agricultural patterns, transportation links and structures, even underground structures. The accompanying photos illustrate the advantages of multispectral scanning over conventional aerial photography. The picture below is an aerial photo of a portion of the Chaco Canyon Anasazi site; at left is a scanner image of the same area. The circled portion of the scanner image shows a number of blue patches which are not in evidence in the aerial photo. The blue patches proved to be kivas, large underground burial or ceremonial chambers. Analysis of other images similarly showed features not identifiable in aerial photos.

Impressed by the results of the Chaco Canyon survey, the National Park Service contracted with the Technology Applications Center for another scan-analysis study of a different Anasazi site, this one at Bandelier in north central New Mexico.

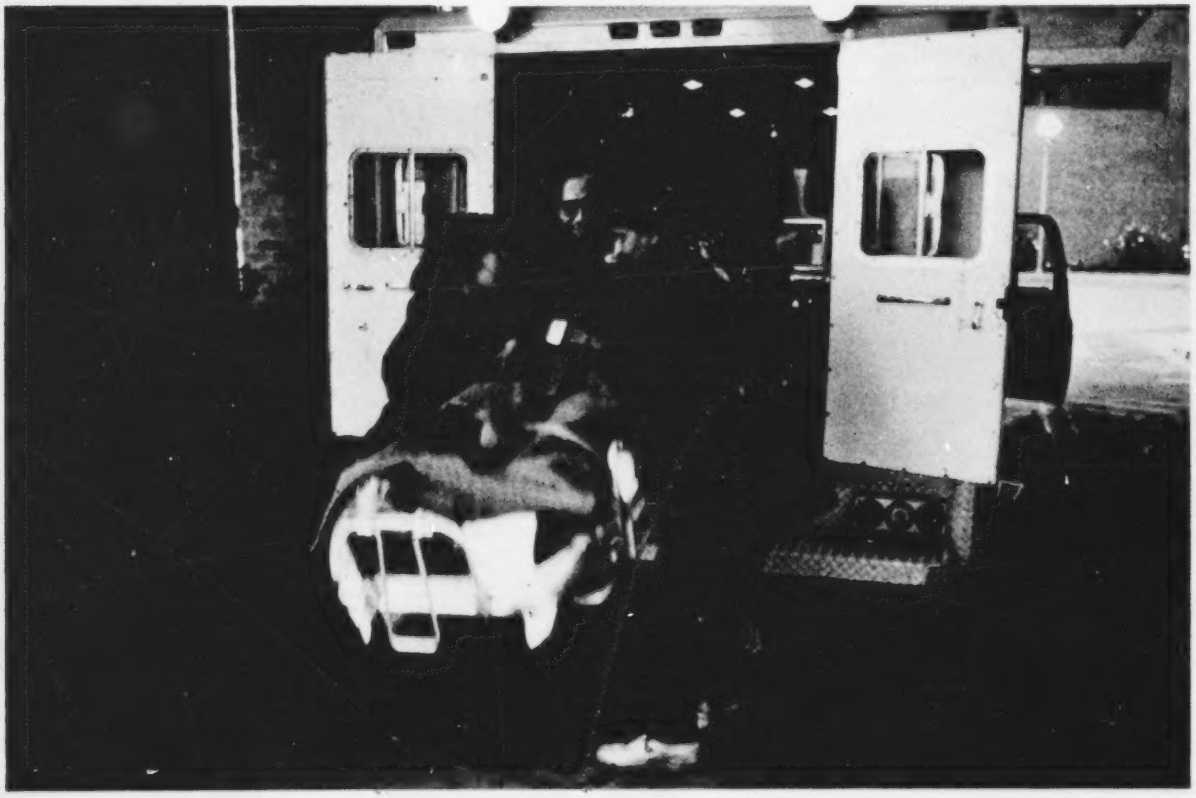
ST. VINCENT CHARITY HOSPITAL

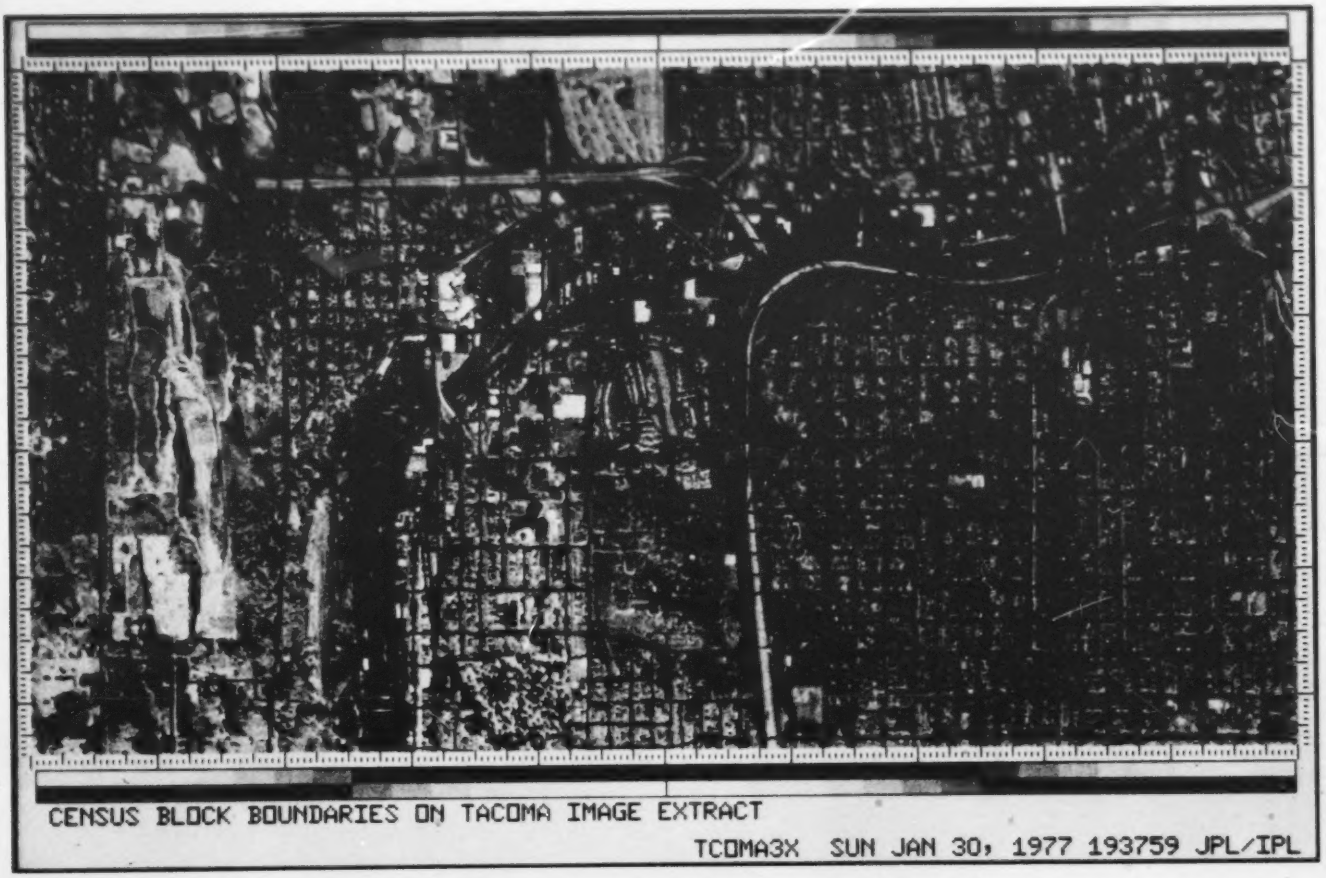
Medical Telemetry Telemetry is the process whereby physiological or other data is acquired by instruments, translated into radio signals and sent to a receiving station where the signals are decoded and recorded. Extensively used in space operations, it is finding new Earth applications, among them transmission of medical data between emergency vehicles and hospitals. For example, transmission of an electrocardiogram from an ambulance to a hospital enables a physician to read the telemetered EKG and advise ambulance attendants on emergency procedures.

Central Medical Emergency Dispatch (CMED) operates as a regional emergency medical communications center for Cleveland, Ohio and Cuyahoga County. The CMED system includes radio and telephone communications from hospital-to-hospital and from ambulance-to-hospital, but for improved emergency life support CMED sought to add a county-wide telemetry capability. The problem was that there were only eight radio frequencies available for telemetry and there were more than 30 potential users in Cleveland alone. This created the possibility of signal interference that would disrupt transmission of an emergency patient's vital signs. What was needed was a coordinated plan for installation and operation of telemetry equipment.

NASA's Lewis Research Center volunteered its expert assistance. The Center's engineers studied the systems of other telemetry using cities, surveyed area hospitals to assure compatibility of telemetry equipment, and advised what types of equipment would be needed in emergency vehicles and at the various hospitals. The Lewis plan suggested that CMED be designated the central coordinating agency for the Cuyahoga County system, monitoring all telemetry frequencies and, when requested, assigning one not in use or one to be used at a sufficient distance that it would create no interference problem.

The plan was adopted and installation of equipment began last year. The Cuyahoga County system is expected to be in use this year and telemetry may eventually be expanded to a five county network in Ohio.





Land Use Planning Computer technology, aerial photography and space imagery are being combined in a NASA community services program designed to help solve land use and natural resource planning problems.

As urban areas grow, so grows the need for comprehensive, up-to-date information on which to base intelligent decisions regarding land use. State and local planners need information such as the nature of urban change; where the changes are occurring, how they affect public safety, transportation, the economy, tax assessment, sewer systems, water quality, flood hazard, noise impact and a great variety of other considerations. Most importantly they need continually updated maps. Preparing timely maps, gathering the essential data and maintaining it in orderly fashion are becoming matters of increasing difficulty.

The NASA project, which has nationwide potential for improving efficiency in the planning process, is a pilot program focused on Tacoma, Washington and surrounding Pierce County. Its key element, developed by Jet Propulsion Laboratory (JPL), is a computerized Land Use Management Information System (LUMIS). LUMIS went into operation in Tacoma on a limited basis last year; it will be expanded to handle additional city planning functions and it may eventually include all of Pierce County.

The LUMIS computer stores and monitors land use and zoning maps, census, housing and other data records. It gets mapping input from ground surveys, aerial photography (photo) and satellite imagery. The system develops a geographic and analytical profile of the whole urban area, and planners can retrieve any portion of the information, presented on a graphic display. LUMIS is expected to improve data reporting, cut down on duplication of effort and save considerable time in the planning and management processes.

In a companion program, NASA funded JPL to develop a similar Image Based Information System (IBIS) for coverage of broader areas. IBIS will get high altitude mapping input from a NASA U-2 research plane operated by Ames Research Center and from Landsat Earth resources satellites. The system will be used by Tacoma and Pierce County as part of a three-state natural resources inventory in Washington, Oregon and Idaho.

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Aerospace spinoffs rarely occur automatically. NASA's Technology Utilization Program encourages them through carefully designed and structured programs for the benefit of industry and public sector institutions

Technology Utilization

A comprehensive nationwide effort seeks to expedite and broaden the secondary application of aerospace technology

Recycling Technology

Like our forests, our rivers, our oil and minerals, the vast storehouse of aerospace technology generated by NASA programs of the past 20 years is a national resource. Since technology is transferable, this wealth of aerospace lore is an important asset in that it offers potential for new applications. It becomes even more important when the potential is translated into reality, when the technology is put to work as a stimulant to national productivity.

That is one of NASA's jobs. The instrument of stimulus is the Technology Utilization Program. Simply stated, the program's aim is to get aerospace technology out of the storehouse and into the mainstream of the national economy, thereby producing bonus return on the aerospace investment.

Technology's role as an invigorant for economic growth is well established. The accumulation of technical knowledge provides a foundation for development of new products and processes, and leads to more effective use of labor, capital and natural resources; this adds up to expanded productivity. Increased productivity means more jobs, more wages, greater profits for management and higher levels of national income. In short, productivity is the key element of a nation's prosperity, and technology is its pump-primer.

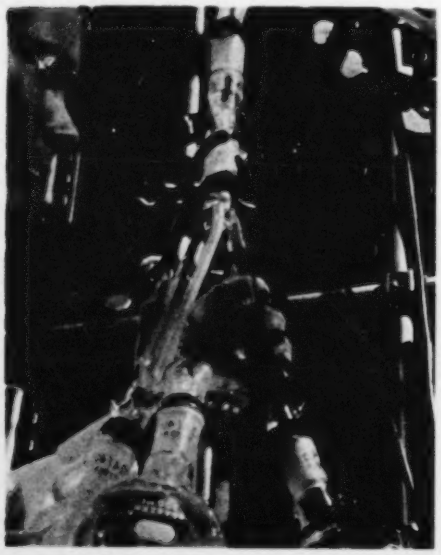
In drafting the legislation that became the National Aeronautics and Space Act of 1958, the Congress took due note of the potential value of aerospace generated know-how. A provision of the Act requires that NASA "shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

NASA has responded to that mandate in impressive fashion. In 1962, the agency established the Technology Utilization Program, a concerted effort designed to accelerate and broaden the transfer of aerospace technology to other sectors of the economy. In the 16 years that have since elapsed, literally thousands of spinoffs have been effected; they range from simple everyday conveniences to major systems that help solve some of society's pressing problems.

Focal point of the program is the Technology Utilization Division, headquartered in Washington, D.C., which coordinates the activities of a nationwide network of technology transfer catalysts. These technologists provide a link between the developers of aerospace technology and those who might effectively reuse the technology in non-aerospace applications. Their job is to keep abreast of aerospace technical advances, seek opportunities for secondary utilization, promote interest among prospective users, and provide assistance to expedite the transfer process.

NASA employs a variety of mechanisms to meet the objectives of the Technology Utilization Program. Amplified on the following pages, they include:

- Publications which detail new technologies developed in NASA programs.
- Technology Utilization Officers, located at each of NASA's 10 field centers, who serve as regional program managers.
- A number of Industrial Applications Centers, channels through which industrial and other potential users may avail themselves of scientific, technical and management information and expertise.
- A Computer Software Management and Information Center, which provides aerospace-developed and other computer programs adaptable to the needs of industry and government agencies.
- State Technology Applications Centers, which focus on opportunities for applying aerospace technology to the specific problems and needs of state and local governments.
- Application teams, multidisciplinary groups of technologists who provide technology-matching and problem-solving assistance to public sector organizations.
- Applications engineering projects, in which NASA undertakes to adapt existing aerospace technology to meet specified needs of other government agencies and public sector institutions.



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Spreading The Word An essential first step in promoting broader utilization of NASA technology is letting potential users know just what NASA-developed information and technologies are available. This is accomplished by means of a series of publications.

Under the provisions of the National Aeronautics and Space Act, NASA contractors are required to furnish written reports "containing full and complete technical information concerning any invention, discovery, improvement or innovation" which may be developed in the course of work for NASA. These reports provide input to NASA's principal technology utilization publication, *Tech Briefs*. Issued quarterly, *Tech Briefs* is a current-awareness medium and a problem-solving tool for its industrial subscribers, in that each issue contains information on more than 100 newly-developed processes, advances in basic and applied research, innovative concepts, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

A special feature of *Tech Briefs* is a section on "New Product Ideas," innovations stemming from NASA research that appear to have partic-

ular promise for commercial application. Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on the new product or process deemed worthy of commercialization.

Tech Briefs enjoys favorable acceptance among its many industrial readers; the list of subscribers now numbers more than 30,000 and it is growing annually. The process of spreading the word is additionally aided by a cooperative industrial trade press, which republishes *Tech Briefs* information for expanded circulation. Last year, innovations reported in *Tech Briefs* generated over 100,000 requests for additional technical information, concrete evidence that the publications program is playing an important part in inspiring broadened secondary use of NASA technology.

Subscription to *Tech Briefs* is free to engineers in U.S. industry, business executives, state and local government officials and other potential users of aerospace technology. The publication may be obtained by writing to Director, Technology Utilization Division, NASA Scientific and Technical Information Facility, Post Office Box 8756, Baltimore-Washington International Airport, Maryland 21240.

Another technology utilization publication deals with NASA-patented inventions available for licensing, which number more than 3,500. NASA sometimes grants exclusive licenses to encourage early commercial development of aerospace technology, particularly in those cases where considerable private investment is required to bring the invention to the marketplace. Non-exclusive licenses are also granted, to promote competition and bring about wider use of NASA inventions. A summary of all available inventions, updated semi-annually, is contained in the *NASA Patent Abstracts Bibliography*, which can be purchased from the National Technical Information Service, Springfield, Virginia 22161.

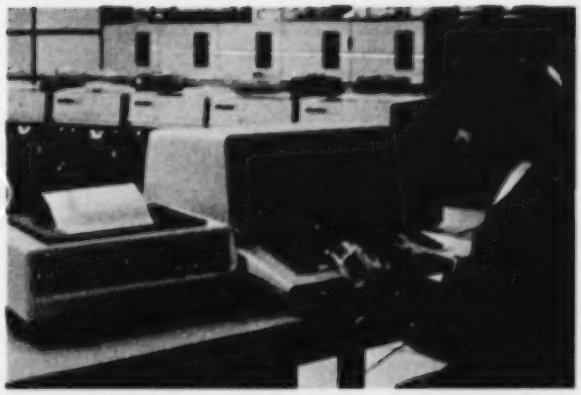
NASA also publishes *Computer Program Abstracts*, an announcement bulletin which advises of government-developed computer programs available for adaptation to industrial or civil use. *Computer Program Abstracts* can be obtained through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

In addition to these regular publications, NASA publishes a variety of special publications—reports, technical handbooks, data compilations—to acquaint the non-aerospace user with NASA advances in various states-of-the-art. Examples include new developments in welding and soldering, lubricants and lubricating techniques, human factors engineering, sterilization and decontamination. These publications are available through the Superintendent of Documents, U.S. Government Printing Office. A list of available titles may be obtained by writing the Director, Technology Utilization Division, at the address listed above.

Information Retrieval and User Service To promote technology transfer within the nation's industrial complex, NASA operates a network of Industrial Applications Centers (IACs), whose job it is to provide information retrieval services and technical assistance to industrial clients. The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval.

Through the IACs, industry has access to some 10 million documents, the world's largest repository of technical data. About 1.5 million of these documents are NASA reports covering every field of aerospace activity. In addition, the data bank includes the continually updated contents of 15,000 scientific and technical journals, plus thousands of published and unpublished reports compiled by industrial researchers and by government agencies other than NASA. Each month another 50,000 documents are added to this wealth of technical information.

The IACs seek to broaden and expedite technology transfer by helping industry in finding and applying information pertinent to a company's projects or problems. The philosophy behind the IACs is that it is wasteful to "reinvent the wheel," that there is no need to duplicate research already accomplished and thoroughly documented in the data bank. By taking advantage of IAC services, individual businesses can save time and money and the nation benefits through increased industrial efficiency and productivity.



Seven in number, the IACs are located at university campuses across the country, each serving a geographical concentration of industry. The IACs also have off-site representatives serving industrial clients in many major cities and their surrounding areas. Additionally, there are technology coordinators at six NASA field centers who perform the important function of matching on-going NASA research and engineering with client interests.

Staffed by scientists, engineers and computer retrieval specialists experienced in working with companies, the centers provide three basic types of services. To an industrial firm contemplating a new research and development program or seeking to solve a problem, they offer "retrospective searches"; they probe the data bank for relevant literature and provide abstracts or full-text reports on subjects applic-

able to the company's needs. IACs also provide "current awareness" services, tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields with a minimal investment of time. Additionally, IAC applications engineers offer highly skilled technical and interpretive assistance in applying the information retrieved from the data bank to a company's best advantage. The IACs charge a nominal fee for their services. For further information on the nature of these services, interested firms should contact the Director of the nearest IAC. Addresses are shown on page 124.

A supplement to the IAC network is the relatively new State Technology Applications Center (STAC) program. Its goal is to facilitate technology transfer to state and local governments, as well as to private industry, by working with existing state mechanisms for providing technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state. In effect, the STAC program is a gap-filler, focusing on areas not normally served by the IACs. In this manner, NASA hopes to increase its technology transfer effectiveness, especially in the less industrialized states and among small businesses.

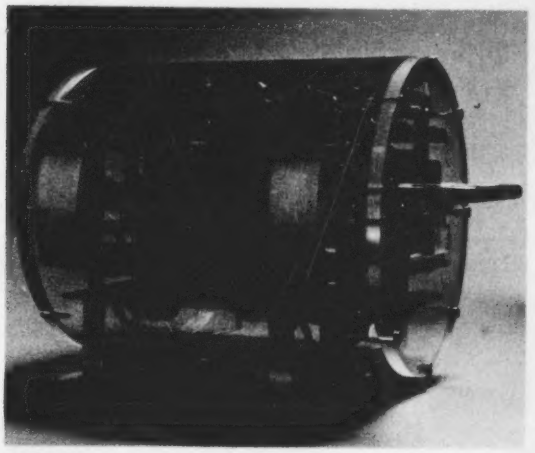
A related service to industry is provided by NASA's Computer Software Management and Information Center (COSMIC) at the University of Georgia. COSMIC collects, screens and stores computer programs developed by NASA and other government agencies. Adaptable to secondary use by industry, government or other organizations, these programs perform such tasks as structural analysis, electronic circuit design, chemical analysis, design of fluid systems, determination of building energy requirements and a variety of other functions. COSMIC maintains a library of some 1600 computer programs, which are available to users at a fraction of their original cost. This facet of NASA's industrial assistance effort represents one of the largest and most successful areas of technology transfer.

Technology Applications The Environmental Protection Agency (EPA) needed a small, portable device for monitoring water quality, to be deployed either from small boats or helicopters. EPA asked NASA for assistance. With contractor help, NASA's Langley Research Center developed a system which incorporates several aerospace technologies, particularly microelectronics, for processing water samples and automatically transmitting the resulting data. Shown undergoing test in the above photo, the Water Quality Package will be demonstrated to EPA this year.

This is an example of NASA's "applications engineering" effort, part of the Technology Utilization Program. Applications engineering is the use of NASA expertise to redesign or reengineer aerospace technology for the solution of problems specified by federal agencies or other public sector institutions.

Applications engineering projects originate in one of three ways. The example just cited illustrates how a government agency may ask NASA directly for assistance in the solution of an important problem. A second way is for a technologist at one of NASA's field centers to perceive the possible solution of a public sector problem by adapting existing NASA technology to meet that need. His proposal is then reviewed by the Technology Utilization Division for technical feasibility, cost and other considerations. Project approval usually results in a cooperative, cost-sharing effort between NASA and the user agency; a project normally includes design, development, evaluation and field testing of prototype hardware.

The third way an applications project may originate represents an innovative concept used by NASA to transfer technology to solve important public sector problems. The key elements are Application Teams consisting of several scientists and engineers who represent different disciplines. Located at research institutes and universities, these teams are important components of NASA's Technology Utilization Program.



The teams contact public sector agencies, medical institutions and trade or professional organizations to learn what significant problems might be susceptible to solution through application of NASA technology. Having identified a problem, they contact appropriate individuals at NASA field centers to determine what existing technologies might be applied to the problem at hand. Matching technology to need, the teams often conduct technology demonstrations as a first step toward bringing about commercialization or institutional acceptance of the technology transfer. There are six application teams; they concentrate their efforts in the fields of medicine, public safety, transportation, and in improving manufacturing processes for increased industrial productivity.

Some additional examples of technology applications are illustrated on these pages. The upper right photo shows an Ocean Bottom

Seismometer Tape Recorder developed by Goddard Space Flight Center for the U.S. Geological Survey (USGS). USGS uses underwater seismometers to record earthquakes and their impact on Earth's crustal structure. The large size of existing recorders precludes their use in very deep waters; small structures can best withstand the extreme pressures. For ocean bottom duty under high pressure, USGS wanted a small, low cost tape recorder which nonetheless had to have high capacity for recording data. Goddard provided it by redesigning a recorder used aboard spacecraft.

The device pictured at bottom left is called a LIXIscope, which stands for Low Intensity X-ray Imaging Scope. An adaptation of a technique for studying x-ray sources in space, the LIXIscope is a small, battery-powered, portable x-ray instrument which produces an instant image with a small source of radioactive material. Built by Goddard Space Flight Center, the unit offers significantly reduced radiation dosage to the patient along with high potential for use in medicine, dentistry and industry. Its portability also makes possible emergency use in field situations where immediate fluoroscopic examination is indicated, for example, on-site scanning for possible bone injuries to athletes or detection of gas leaks in pipe lines.

At bottom right a technician is readying a NASA-developed mobile laboratory for testing roadway skid resistance, information needed by highway departments for resurfacing roads to reduce accidents caused by skidding. Skid test trailers are commercially available but they are expensive; many communities can't afford them. To promote improved road safety, NASA's Langley Research Center sought to develop an affordable skid tester. The result is the Diagonally-Braked Vehicle, a standard auto which employs a comparatively inexpensive "pulsed-braking" method of measuring skid resistance, an adaptation of techniques used to determine the skid resistance of aircraft runways. Last fall, skid resistance tests were conducted at Dayton, Ohio, using the NASA vehicle and a commercially available skid tester to verify recorded measurements. These week-long tests were witnessed by representatives of the Federal Highway Administration, Ohio Department of Transportation and the Transportation Research Board, among others. All expressed enthusiasm for the Diagonally-Braked Vehicle.

The NASA Technology Transfer Network

The NASA system of technology utilization personnel and facilities extends from coast to coast and provides geographical coverage of the nation's primary industrial concentrations. Symbols on the map indicate:

- ● NASA field centers, each of which includes a Technology Utilization Officer who manages Center participation and regional technology transfer activities.
- ▲ Industrial Applications Centers, which provide information retrieval services and technical assistance in applying the information gathered.
- △ State Technology Applications Centers, which provide technology transfer services similar to those of IACs, but only to state government and small businesses within the state.
- ■ The Computer Software Management and Information Center (COSMIC), which offers government-developed computer programs adaptable to secondary use.
- ○ Application teams, which work with public agencies in applying aerospace technology to solution of public sector problems.

The following pages list key technology utilization personnel and addresses of the various facilities. For information of a general nature about the Technology Utilization Program, address inquiries to Director, Technology Utilization Division, NASA Scientific and Technical Information Facility, Post Office Box 8756, Baltimore-Washington International Airport, Maryland 21240.

NASA Field Centers

AMES RESEARCH CENTER
National Aeronautics & Space Administration
Moffett Field, Calif. 94035

Technology Utilization Officer: *Charles C. Kubokawa*
Phone: (415) 965-5554

HUGH L. DRYDEN FLIGHT RESEARCH CENTER
National Aeronautics & Space Administration
P.O. Box 273
Edwards, Calif. 93523

Technology Utilization Officer: *John C. Drane (acting)*
Phone: (805) 258-8787

GODDARD SPACE FLIGHT CENTER
National Aeronautics & Space Administration
Greenbelt, Md. 20771

Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 982-6242

LYNDON B. JOHNSON SPACE CENTER
National Aeronautics & Space Administration
Houston, Texas 77058

Technology Utilization Officer: *John T. Wheeler*
Phone: (713) 483-3809

The network has access to more than 10 million documents worldwide

JOHN F. KENNEDY SPACE CENTER
National Aeronautics & Space Administration
Kennedy Space Center, Fla. 32899

Technology Utilization Officer: *Raymond Cerrato*
Phone: (305) 867-2780

LANGLEY RESEARCH CENTER
National Aeronautics & Space Administration
Langley Station
Hampton, Va. 23655

Technology Utilization & Applications Programs Officer: *John Samos*
Phone: (804) 827-3281

LEWIS RESEARCH CENTER
National Aeronautics & Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135

Technology Utilization Officer: *Paul Foster*
Phone: (216) 433-4000, Ext. 6422

GEORGE C. MARSHALL SPACE FLIGHT CENTER
National Aeronautics & Space Administration
Marshall Space Flight Center, Ala. 35812

Director, Technology Utilization Office: *Aubrey D. Smith*
Phone (205) 543-2224

NASA JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, Calif. 91103

Technology Utilization Officer: *John C. Drane*
Phone: (213) 354-6420

WALLOPS FLIGHT CENTER
National Aeronautics & Space Administration
Wallops Island, Va. 23337

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (703) 824-3411, Ext. 2201

NASA Biomedical Application Teams

RESEARCH TRIANGLE INSTITUTE (RTI)
P.O. Box 12194
Research Triangle Park, N.C. 27709

Richard Scearce, Ph.D., director
Phone: (919) 549-8311, Ext. 2640

STANFORD UNIVERSITY SCHOOL OF MEDICINE
Cardiology Division
Biomedical Technology Transfer
701 Welch Road, Suite 3303
Palo Alto, Calif. 94303

Donald C. Harrison, M.D., director
Phone: (415) 498-5935

ADVISORY CENTER FOR MEDICAL TECHNOLOGY & SYSTEMS
University of Wisconsin
1500 Johnson Drive
Madison, Wisc. 53706

William N. Fetzner, Ph.D., director
Phone: (608) 263-2735

NASA Technology Application Teams

PUBLIC TECHNOLOGY INC.
1140 Connecticut Ave., N.W.
Washington, D.C. 20036

Roger Lubin, director
Phone: (202) 452-7700

STANFORD RESEARCH INSTITUTE
333 Ravenswood Ave.
Menlo Park, Calif. 94026

Tom Anyos, Ph.D., director
Phone: (415) 326-6200, Ext. 2864

IIT RESEARCH INSTITUTE
10 West 35th Street
Chicago, IL 60616

John D. Meyer, director
Phone: (312) 567-4609

Industrial Applications Centers

AEROSPACE RESEARCH APPLICATIONS CENTER (ARAC)
1201 East 38th Street
Indianapolis, IN 46205

E.G. Buck, director
Phone: (317) 264-4644

KNOWLEDGE AVAILABILITY SYSTEMS CENTER (KASC)
University of Pittsburgh
Pittsburgh, PA 15260

Edmond Howie, director
Phone: (412) 624-5211

NEW ENGLAND RESEARCH APPLICATION CENTER (NERAC)
Mansfield Professional Park
Storrs, CT 06268

Daniel Wilde, Ph.D., director
Phone: (203) 468-4533

NORTH CAROLINA SCIENCE AND TECHNOLOGY RESEARCH CENTER (NC/STRC)
P.O. Box 12235
Research Triangle Park, NC 27709

Peter J. Chenery, director
Phone: (919) 549-0671

TECHNOLOGY APPLICATIONS CENTER (TAC)
University of New Mexico
Albuquerque, NM 87131

Stanley Morain, Ph.D., director
Phone: (505) 277-3622

WESTERN RESEARCH APPLICATIONS CENTER (WESRAC)
University of Southern California
University Park
Los Angeles, CA 90007

Radford King, director
Phone: (213) 741-6132

TECHNOLOGY USE STUDIES CENTER (TUSC)
Southeastern State University
Durant, OK 74701

C. Henry Gold, Ph.D., director
Phone: (405) 924-0121, Ext. 413

State Technology Applications Centers

NASA/UNIVERSITY OF FLORIDA STATE TECHNOLOGY APPLICATIONS CENTER
University of Florida
311 Weil Hall
Gainesville, FL 32611

Robert A. Ramey, Ph.D., director
Phone: (904) 392-6626

NASA/UNIVERSITY OF KENTUCKY STATE TECHNOLOGY APPLICATIONS PROGRAM
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506

William R. Strong, manager
Phone: (606) 258-4632

COSMIC

112 Barrow Hall
University of Georgia
Athens, Ga. 30602

Harold G. Hale, Jr., director
Phone: (404) 524-3265

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